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Contents

SILICON CHIP
Vol.30, No.6; June 2017
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Features & Reviews

12 The Flettner Rotating Sail and the Magnus Force
When the wind blows on a rotating surface, strange forces are generated. It's called the Magnus Force and a century-old application, the Flettner Rotating Sail, is currently being trialled on some huge ships – by Ross Tester

38 LTSpice – simulating and circuit testing
SPICE is a powerful, yet easy-to-use tool which allows you to use a computer to simulate how a circuit will behave without actually having to build it. We show you how to use this FREE program – by Nicholas Vinen

78 Getting Started with the Micromite, Part 4
This month we look at some of the more specialised Micromite features, such as power saving, using touch-sensitive LCD panels and handling button presses, storing data in non-volatile memory and interrupt routines – by Geoff Graham

86 Review: Keysight's 9917A 18GHz Spectrum Analyser
This portable powerhouse has far more features and options than anything else we've seen – in fact, we couldn't even play with all of them in the short time we had. But what we did try left us very impressed – by Nicholas Vinen

Constructional Projects

18 All-new 10-Octave Stereo Graphic Equaliser
*Not only does it look pretty snazzy in its laser-cut black acrylic case, it has performance to match. But the really good news is it's much cheaper than earlier designs **and** (despite using some SMDs) is easy to build – by John Clarke*

28 Arduino-based Digital Inductance & Capacitance Meter
It will measure inductance (L) from 10nH to 100mH+ and capacitance (C) from 1pF to 2.7uF – much more accurately than DMM-based units. Based on an Arduino Uno (or equivalent) it also offers digital readout – by Jim Rowe

61 El Cheapo Modules, Part 7: LED Matrix displays
It has a MAX7219 serial LED display chip and comes complete with a plug-in 8x8 LED matrix display. But it can also drive an 8-digit 7-segment LED display – by Jim Rowe

66 New Marine Ultrasonic Anti-Fouling Unit, Part 2
Last month we introduced our new Ultrasonic Anti-Fouling Unit to keep barnacles (and other marine growth) under control. Now we get onto the good part: putting it all together and mounting it in your boat – by John Clarke

Your Favourite Columns

46 Serviceman's Log
Fixing the food processor that wouldn't – by Dave Thompson

94 Vintage Radio
HMV's 1951 portable model B61D – by Associate Professor Graham Parslow

100 Circuit Notebook
(1) Low power switched capacitor DC/DC converter for rechargeable batteries
(2) PICAXE-based dual temperature datalogger
(3) Arduino 3D printer heat bed controller

Everything Else!

2 Publisher's Letter
4 Mailbag – Your Feedback
92 Product Showcase
104 SILICON CHIP Online Shop
106 Ask SILICON CHIP
111 Market Centre
112 Advertising Index
112 Notes and Errata

It all started when Flettner fitted rotating masts to a ship and sailed it across the North Sea. Now large ship-owners are taking notice – Page 12

Woops – wrong Spice! But LTSpice can help you understand complex circuits without building them – Page 38

WOW! Our new Stereo Graphic Equaliser not only looks the part . . . it has specs that match its appearance – Page 18

You asked for more Arduino projects . . . well, here's an Arduino-based Digital Readout LC Meter that's accurate and easy to build – Page 28

If you own a decent-sized boat, you must read our article on building a high-performance Ultrasonic Anti-Fouling Unit – Page 66

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Publisher's Letter

SPICE streamlines circuit design

This month's tuitional article on the topic of SPICE simulation (page 38) will have a particular interest for readers who would like an insight into the ways in which we produce the circuits for our projects. These days we seldom bother with building a "bird's nest" or a protoboard layout on the workbench. There are a number of reasons for this.

First, the components are simply too small and usually have too many pins to produce a bird's nest. Second, even if we did wire up a bird's nest or a protoboard, the stray wiring capacitance and inductance would be so unpredictable that reliable operation would be unlikely. Or if it did work by some fluke, it might be very hard to reproduce the same performance on a PCB.

Second, the key devices in many circuits are now surface-mount types and the only way to wire these into a prototype layout would be to use adaptor boards of some sort. Even then, stray wiring capacitance and inductance would be a problem.

Finally, many of our microprocessor circuits, particularly those using the PIC16F88, are variations on past themes and the real "smarts" are in the software. The major part of the design is in writing and debugging the program.

So in virtually every project these days, we proceed directly to producing a prototype PCB, designed using the powerful and highly regarded CAD package, Altium Designer (produced in Australia, by the way).

Part of the design process for the PCB will involve trying to make provision for any circuit changes which might prove to be necessary, without producing another iteration of the board. If this can be done successfully, we save time and money. But the PCB design does not simply involve using a pencil circuit sketch or a more elegant CAD rendition which becomes the "netlist". In the case of most analog circuits, we need to run SPICE simulations to ensure that the proposed design will actually work.

In fact, SPICE simulation takes the place of the bird's nest or the more elaborate protoboard layout. As described in this month's article on SPICE simulation, this process allows as many iterations as we need, to be confident that the circuit will work as intended. Nor is there any need to do any instrument testing, because the SPICE program will simulate that too.

So for example, SPICE can show how a filter circuit will respond to an impulse, or model the input surge current into a power supply, or show how deliberate overloads will affect the circuit – all without blowing a single fuse or letting the "smoke out" of any expensive semiconductors.

However, despite all that initial simulation, after assembling the prototype PCB we sometimes find that the performance is not what we wanted. This can happen no matter how carefully the PCB has been laid out – and this happened with the Graphic Equaliser in this month's issue.

You can see that there would be no practical way in which that circuit could be prototyped in the traditional way – it is simply too large and complicated. Perhaps inevitably though, the initial performance of the prototype PCB was not up to scratch. Its boost and cut were excessive and the distortion and residual noise were too high.

And here I will let you into a secret: we had not done any initial SPICE simulations, because the circuit was a miniaturised variation of a design we presented back in 1989. Sorting out the problems with the prototype could have taken many days of component changes and subsequent testing but we did not have time for that. Instead, we simply did a few SPICE simulations of the key circuit sections and this pointed to the solution. The results can be seen on page 18 of this issue.

Leo Simpson

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MAILBAG – your feedback

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Software copy protection leads to bad user experience

I have had an experience with the Virtins Multi Instrument software that I believe should be brought to the attention of your readers.

I built the USB Test Instrument Interface for PCs (September 2012) and following your recommendation in the accompanying article, I purchased the Virtins software to use with it. I should add that your excellent magazine is an innocent bystander in this unfortunate situation.

The computer on which the software was installed suffered a motherboard failure and since it would not boot up, I was unable to generate a "Removal Code" from the Virtins software in order to transfer the license. Once a new motherboard was installed, the computer was returned to a functional state and all the software on it functioned except for Virtins.

I referred the problem to Virtins and was told that I would have to pay for a new license. Their reasoning was "the motherboard contains most of the identity parameters of a computer and thus if it is replaced, the computer becomes virtually a new computer".

I find this reasoning to be completely ridiculous. The replacement motherboard is very similar in specification to the failed unit and the sole reason for its replacement was a hardware failure.

I am extremely unhappy about being made to pay for another licence for a product for which I have already paid. I wonder how many of the users of this product are aware that a hardware failure of this nature could cost them an additional licence fee from Virtins. Since motherboard failures are not unknown in the computer world, this situation could recur at any time to any user of the software.

If Virtins were an Australian company, I would certainly be lodging a complaint with the ACCC for what I regard as unethical conduct at the very least. As it is, I either have to pay another licence fee or find alternative software to use. With the latter possibility in mind, can you recommend an alternative product, since it is very difficult to accept paying twice for the same thing?

Barrie Davis,
Hope Valley, SA.

Editor's response: the designer of the USB Test Instrument Interface, Jim Rowe, did some searching and came up with the following two possible alternatives:

1. True Audio (www.trueaudio.com) still has their TrueRTA software available but this is only a virtual audio real-time analyser.

2. Digilent (a National Instruments offshoot – http://store.digilentinc.com/) has a free-to-download virtual multi-instrument software application called Waveform 2015, but we aren't sure that it is compatible with our September 2012 USB Virtual Instrument. It would be worth a try, though.

Finally, it may be worth complaining to the ACCC if you believe a company is in breech of Australian consumer law, even if that company is based overseas.

While it's unlikely in this case, the ACCC has taken action with overseas companies on the basis that if they do business with Australians, Australian consumer law still applies. For example, see: www.accc.gov.au/media-release/federal-court-finds-valve-made-misleading-representations-about-consumer-guarantees

Energy savings from better insulation beats cutting aircon in summer

Thank you for another nice edition of SILICON CHIP. Also, thank you for publishing my comments in the April edition. I am curious to see any comments that may be generated by my letter on solar power and wind generators.

When I first saw the cover of April's edition and DRED with the big brother comment, I wondered if it was an April fool's joke. After verifying that it was real, I was a little annoyed.

Another case of bureaucracy making a poor decision. Kevin Rudd was heavily criticised for his home insulation idea but it was a good idea that was very badly implemented.

The reason that I say it was good is that the result would have been lower heat input into homes and hence lower loading on air conditioners in those homes that have them. Instead, the DRED method does nothing to reduce power consumption until the system is close to collapse.

I have to spend a lot of time at home and with only my hobby room air conditioned, I have had to experience a very hot house every day. During the day, the windows became large radiant heaters despite the external shades.

I noticed that it was mainly the lower half of the windows that was hot, so I fixed aluminium coated insulation sheet to corrugated cardboard sheets and sat them in the windows.

The aluminium surface reflects heat outwards and the cardboard is a good insulation besides providing stiffness. This made a large difference; the temperature of the house still increases during the day but at a much slower rate and to a lower maximum.

The correct action of government should've been to promote better insulation of homes in general and thus lower air-conditioning loads and overall system power requirements.

This leads me to suggest a possible future project. I would have liked to measure the incoming solar thermal radiation density using a bolometer. Perhaps SILICON CHIP can do a project based around the solid state equivalent.

Another suggestion for an article. I have worked as a calibration engineer

Solar pool pump/chlorinator/water heater controller wanted

The Publisher's Letter in the May 2017 issue requested feedback on whether a project to feed power to a pool pump and chlorinator would be welcomed. I would probably construct such a project but I have another request. Could the project include the ability to feed a water heater?

It would probably need to monitor the current taken by the water heater to determine whether the thermostat was on demand so that power could be diverted to the pool pump, etc. I currently heat my water with off-peak power because a simple timer on the solar power does not prevent the water heater drawing full price power from the grid.

John Nestor,
Woorim, Qld.

Leo Simpson comments: That is certainly another potential use for this project; many householders do not own a pool but virtually everyone has an electric water heater (except for those with instantaneous gas heaters).

Another potential use might be to run a roof fan to extract hot air on very hot days. Still, that would not use much power but might reduce aircon use.

I have been racking my brain for other ways to use on-site solar power but I fear that most people will only ever be able to exploit a fraction of it, failing the installation of a battery/inverter, and that is not yet a viable approach since the payback period is likely to be longer than the battery life.

for flow meters and as a laboratory technician and I am very aware of instrument accuracy.

With all the claims being made of unbelievable accuracy of various physical quantities, I would like to suggest an article on accuracy and quality control with particular reference to the practical limits of measurement.

I keep seeing ridiculously accurate claims about physical quantities, both stated and implied. It concerns me that most people (including SILICON CHIP readers) do not realised that they are being misled.

George Ramsay,
Holland Park, Qld.

Climate Change is not a settled science

I have a very different view to that of Ian Paterson from Fullarton, SA. In his Mailbag letter (page 6, March 2017), it seems that if you do not agree with Mr Paterson's view of things it shouldn't be published.

Regarding the Publisher's Letter, we don't have to read it. If we are prepared to argue about it, it shows that we are interested too, even if we won't admit it. This is one of the better bits of SILICON CHIP.

Secondly, the Mailbag pages are definitely useful; it shows what the rest of the thinking people in Australia think and other wide-ranging topics. I would not mind if even more space was devoted to it.

On the topic of Climate Change, this is not a settled subject. Historical records show that the climate has been changing for centuries. Frost Fairs were held on the Thames in London in the 1600s, having been previously much warmer.

There is no question that climate is changing. The real question is: does man have anything to do with it?

The trouble is that those who say he has, have grabbed the attention of the media, and the ones who say no or little effect, don't get the attention they deserve. Which brings us to SILICON CHIP; if a monthly scientific magazine can't talk about this and energy related topics, who can?

Just for the record, I'm a long-term reader, I am a practicing Christian and I believe God is in charge. I do believe in Climate Change but have grave doubts about Man being the principle cause and if we can do anything about it, it should certainly be done in a cost effective manner.

Graeme Burgin,
Ararat, Vic.

Comment: many Christians regard coal and other fossil fuels as a gift from God and that Man should exploit this gift. Even most unbelievers would agree with that.

Vintage Radio article on HMV Little Nipper brings back memories

The Vintage Radio column in the May 2017 issue, by Charles Kosina, was a 60+ year journey down memory lane for me. I first performed inspection work on the "Nipper" assembly line, to later take up further tasks for HMV radio product design.

This model was the second version; the first used octal sockets with a 4-valve reflex design (to save the cost of a valve).

The same (64) electrics reappeared in a different smaller (louvred)

Mailbag: continued

eFuse pluggable resistors to quickly change trip current

I recently built the eFuse kit (based on the April 2017 project and supplied by Altronics) and made a little amendment to be able to quickly and easily swap out R1 and R2 (to suit each specific application).

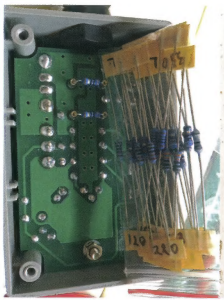
I got the idea from building the 6-Digit LED GPS Clock (December 2015, January 2016) where IC socket strips were used as LED holders. Basically, I broke a socket strip up into single pins and soldered them in place of the resistor leads.

Now, when unscrewing the back of the box, I have quick access to swap out the resistors; see the attached photo at bottom left.

I have also included two of each resistor in a small bag and re-created the selection table on a sticker printed from a Brother label printer which I stuck to the inside of the lid (see photo at bottom right).

Brett van der Leest, Footscray, Vic.

Editor's note: that's a clever idea but note that the resistors could work loose or become intermittent if they have a poor connection and the eFuse may not function properly. Fitting a rotary switch would be more work but probably less troublesome in the long run.



cabinet until the early 1960s, after which solid-state components progressively took over.

The very clear photos showed the QC practice at the time of inspecting and "blessing" each soldered joint with orange lacquer (Kriesler used green lacquer).

When later servicing the set, one could immediately see which components had been replaced. Also, the photo reveals that the plated chassis, speakers, transformers and coils (but not the MSP, "H" tuning gang) that were made in-house.

Regarding the power cord anchoring, I blush to think how cavalier we were about such things then. Later, SAA rightly had us using three-core mains leads and a pull-resistant crimping grommet as standard.

Regarding tuning dials having call-signs at the time, woe betide any maker who failed to include all Australian stations. Dials had to keep up with additions/changes.

After the station spacing changed from 10kHz to 9kHz, eventually only frequencies were shown; one observed that customers found finding stations harder and ratings went in to confusion!

A feature of all later local HMV transistor radios was to extend the top end of the dial to about 1750kHz, to include the lower-powered UNSW station then located at Concord West.

Neville Snow, Burwood, NSW.

AEMO chief's 2016 warnings of grid collapse

SILICON CHIP readers may be interested in the article at:

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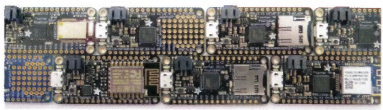

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https://quadrant.org.au/opinion/doomed-planet/2017/04/dead-man-warns-dying-grid/

This article describes comments made in August 2016 by the late Australian Energy Market Operator chief Matt Zema, warning of impending trouble in Australia's electricity grid due to the enormous subsidies provided to "renewable" energy leading to a situation whereby "The system must collapse".

Far from being "sustainable", renewables such as wind and solar are anything but and will continue to represent an enormous drain on the economy with a commensurate decline in Australia's standard of living.

Meanwhile, as Australia is shutting down its coal power stations, leading to some of the highest electricity costs in the world, hundreds of new coal power stations are being built all over the world. It just doesn't make sense.

Dr David Maddison,
Toorak, Vic.

In defence of climate science

I must take issue with Ian Williams' reply (Mailbag, May 2017) to Ian Paterson's comments (Mailbag, March 2017).

When Ian Williams states that "Particular areas of science are well resourced but regretfully there are often political agendas also running in the present era", he is misleading your readers.

Science, like art, has always required wealthy patronage. Many early scientists were wealthy enough to fund their own investigations but otherwise the science has, in some way or other, had to satisfy or at least not offend whoever was paying the bill.

In that regard, science has always had to be done in a political environment and the modern era is really no different. Any claim that climate science is funded simply because it is popular is absurd.

There are so many powerful interests arrayed against climate science in government and the private sector that climate science would never have started if funding were just the result of a popularity contest, and if it had it would have been quickly shut down. Look at what has been happening in the USA since President Trump took office.

It seems to me that Ian Williams simply does not understand science or scientists. Science succeeds or fails mostly on its ability to describe reality.

If climate science consistently failed to provide reliable predictions funding would have dried up years ago. Furthermore great fame and fortune would accrue to anyone who was able to show why climate science is wrong.

The fact that nobody has succeeded to date is entirely due to the fact that nobody has been able to creditably show how, where or why climate science is wrong overall.

Sure, small anomalies are found and when they are the theory should be adjusted to account for them so that over time the theory becomes more complete and the models more accurate. This is how science operates, and this is how we should operate personally; we should adjust our beliefs so they comport with reality.

continued page 11

Banggood DSO praise and assembly tips

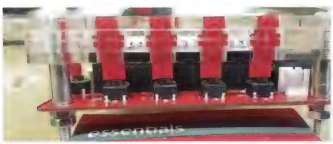
I purchased the Banggood JYE Tech DSO kit which was described by Jim Rowe in the April 2017 issue. Wow – it was the best $28.00 I have spent in a while. It worked first time and I am very impressed with its performance for the price.

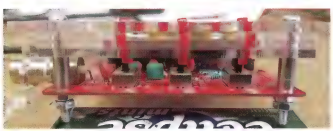
The assembly instructions were very good – step by step for the electronic assembly – I got the version you suggested, with just the through-hole parts to be fitted. Here are a few tips you may want to pass on to other readers, especially for the case assembly:

1. Extend the test loop so it can protrude to the outside of the case.
2. Fold the loop at right angles to the PCB.
3. Assemble from the top PCB downwards, not from the main PCB upwards.
4. Assemble the display PCB on to its carrier before assembling the rest of the case.
5. Re-fit the display board and fit the switch & button extension pieces.
6. Fit the two panels – the ones with the cut-outs/slots for the switch & button extension pieces. They are both needed to obtain the correct spacing for the switches and buttons (see the two photos below). Several of the videos only show fitting one of these panels, a big mistake; the spacing is wrong and the buttons can jam. Then fit the switch and button extension pieces and the top cover.
7. Add the nuts to this assembly (see photos). I used four spacers to ensure that the assembly was not bent by over-tightening the nuts.
8. Add an extra nut, then add the side pieces and back.

Thanks for doing the article on this digital scope. What is next; a function generator?

Mike Abrams,
Capalaba, Qld.





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Feedback on the May issue

SILICON CHIP is to be commended for the use of shortened URLs (some of them can be humongous!) but may I request that you also include the domain to which it is being redirected?

The latest malware technique is "drive-by downloads", whereby merely viewing a site that uses Javascript is sufficient (Windows is especially vulnerable, of course).

Even legitimate sites can be compromised due to insecure CMS tools or poorly-written PHP scripts etc, so knowing the destination in advance would be a good thing. The alternative is to run a script-blocker such as NoScript but I have no idea whether it's available for Windows, as I'm a happy Unix/Linux/Mac bigot.

By the way, your advert on page 29 of the May 2017 issue appears to have several items with the prices lopped off, due to what I assume is the canonical "production error".

And what a huge issue; well done!

Finally, may I suggest a minor change to your on-line shop? If you click "Log out" with items in the trolley, perhaps you could add a warning pop-up? Several times I went to click "Check out" and missed...

Dave Horsfall,
North Gosford, NSW.

Comment: thanks for that feedback and those suggestions.

With respect to the logout warning, we think this would be annoying for many people since they often keep items in their trolley long term, between log-in sessions, to possibly purchase at a future date. We see people complete purchases which were initiated months before, sometimes more than a year. They would get this warning every time they logged out.

The important point is that, even if you do inadvertently log out, those items will still be in your trolley. All you have to do is log back in and then you can immediately check out; the items in the trolley are retained as they are attached to your account.

So we think the inconvenience of accidentally logging out is minor whereas the inconvenience of getting the warning could be significant for some users. Can you suggest a way of implementing this warning that would not adversely affect users who purposefully leave items in their trolley between sessions?

Note that you can also check out by clicking on the trolley icon and then clicking on the "Go To Register (Check Out)" button. Perhaps this is less likely to result in an accidental log-out.

As far as the shortened URLs are concerned, we certainly could change the website to show you the link you are going to be redirected to before it actually happens. But will that necessarily protect you from Javascript vulnerabilities? How will you know, based on the domain, whether it's safe or not?

We think a feature like Firefox's and Chrome's built-in Malware Protection where it warns you, before visiting a site which has been reported as a source of malware, is a better solution. This should work even with immediate redirection, like we have now.

And regarding the problems on page 29, this was actually a bug in InDesign which did not appear during the proof-reading process and it has been fixed for the next issue. Thanks for letting us know anyway.

Lower set-points for air conditioners could save lots of energy

I am writing in reaction to the article on DRED, in the April issue and the fact that the DRED system can switch off or reduce the power drawn by domestic air conditioners.

The amount of work an air conditioner has to do and therefore the electricity it uses, depends on how far below ambient it is trying to cool the room to. Many people set their air conditioner to cool to 22°C.

It would substantially reduce the power it used if set to 25°C. And would reduce it a lot more, if they were set to 28°C. Most people aren't uncomfortable enough to turn their air conditioner on until it gets to that temperature, so they wouldn't really be uncomfortable if on hot days it only cooled to that.

That is what should have been fitted to air conditioners to cut peak power consumption on peak load days. A mechanism that when you set it to an unnecessarily low 22°C, the electricity network could override that and limit it to cooling to 25°C or even 28°C.

It wouldn't require the network to manage which air conditioners were off and for how long and to switch them back on. Just send the signal to the whole network or a branch of it, and the temperature control software already in the devices would implement the power saving.

Arguably, as a planet-saving measure, all air conditioners should by default only give you cooling to 25°C when you set them to cool to 22°C, and 19°C when you tell them to warm to 22°C. Most people wouldn't even notice unless you told them.

Gordon Drennan,
Burton, SA.

Editor's comment: we don't think any authority should have the right to over-ride a householder's decision about their air conditioner's temperature settings.

For example, in Sydney and virtually anywhere further north on the Australian east coast, there can be 25°C days which have relative humidity above 90% and the only way to sleep comfortably is to cool to below this temperature, simply to force the air conditioner to dehumidify the air.

On the other hand, there can be much less humid days where the temperature is above 30°C and we don't need to use air conditioning at all.

Arguably, air conditioners should have a humidity or "comfort" setting.

Contrary to the notion that climate scientists are trying to pull the wool over ours eyes (reliable evidence for which has not been forthcoming).

Climate scientists have been bullied and harassed to prevent them from presenting their science to the general public, science that was paid for out of the public purse. See www.abc.net.au/news/science/2017-03-02/csiro-missing-in-action-on-climate-advice/8479568

Ian Williams said that "All results and arguments need to be listened to."

This is true but only to the extent that such arguments are cogent and accord with the observed facts, and on that score there is no refutation of current climate science presented so far that does that.

The global temperature is rising, and has done so since the start of the industrial age.

Ian tells us that he has "come to believe that it is arrogant for anyone to believe that we can control the Earth's temperature."

I have no doubt there were once people who believe it was "arrogant" for anyone to believe they could fly but we have achieved that and we may one day be able to control the Earth's temperature.

However, I know of nobody who is claiming that we are able to control the Earth's temperature, merely that we are affecting it in a severely negative manner, and that hopefully we can stop doing that before it is too late for life on the planet.

Ian Williams' claim that "the Sun's heat is the source of all weather" is not exactly true, nor is it particularly relevant to the extent that it is true.

The 1991 eruption of Mt Pinatubo in the Philippines "led to a decrease in northern hemisphere average temperatures of 0.5–0.6°C (0.9–1.1°F) and a global fall of about 0.4 °C (0.7°F)" and caused a dramatic reduction in ozone. (Wikipedia)

There is also the effect of radiogenic heating of the earth: the heat generated inside the Earth by radioactive decay has to go somewhere or the Earth's interior temperature would simply keep rising, so the heat has to escape into space through the earth's surface and the atmosphere. Also, the wind is influenced by rotation of the earth.

I think the simple fact that over 95% of the world's scientists accept global warming as fact should tell us that we need to take it seriously.

Not all scientists are climate scientists, but they do understand how science works, and despite its flaws they accept it is by far the best method we have for apprehending the truth.

Now while everybody is entitled to their own opinions they cannot just make up their own facts, simply because if these "facts" are wrong they just aren't facts.

Furthermore, the right of people to say absolutely anything they like is overstated: it is irresponsible, immoral even, to yell fire in a crowded theatre if there is no fire.

In my opinion it is quite irresponsible, at the very least, to propagate ideas, beliefs, or "alternative facts" that are contradicted by the observed evidence and the best theory.

I think that if you disbelieve in something like climate science (or the safety of vaccines, for that matter) which can have extreme impacts on peoples' lives, public safety etc, then your moral responsibility is to shut up until you can present a plausible case for your beliefs.

On an unrelated matter, readers may have heard of EMI susceptibility problems with Keysight U127x series and U128x series handheld multimeters. These have been addressed in Service Notes U1272A-07A and U1281A-02A.

Keysight has instituted a service/exchange program to address the issue. More information (such as where to send your meter but you should phone or email them first) can be found under the Support Specialists tab at www.keysight.com/find/contactus

While it is disappointing to have to deal with problems like this, people should bear in mind that these are complex instruments and that Keysight are not alone with these sorts of problems.

Users and owners of Keysight instruments should also be reminded that there are sometimes firmware updates designed to address issues that arise with their instruments and which are usually free.

I have installed a few now, and while they don't always work without a hitch (you might have to search for the right COM port a couple of times before it's established), they install pretty easily.

Phil Denniss,
Sydney, NSW. SC

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Century-old technology set to save $BILLIONS in fuel costs!

The Flettner Rotating "Sail" and the Magnus Force

by Ross Tester

Some time in the not-too-distant future, you may see large ships with strange-looking spinning towers mounted on their decks. They'll be using the same laws of physics that keeps planes in the air and golf balls travelling further . . . and saving lots of fuel in the process.

The 400m-long Emma Maersk, launched in 2006, is one of the largest container ship in the world, capable of carrying 15,200 shipping containers at a steady 25.5 knots (47km/h).

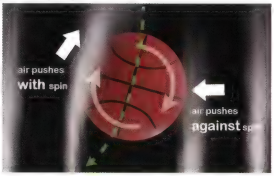
Actually, the "largest" title is *currently* held by the MSC Oscar, capable of carrying 19,224 containers. Even bigger vessels are currently under construction.

But the Emma Maersk held this title for some time. So it's not surprising that she also has one of the world's largest reciprocating engines.

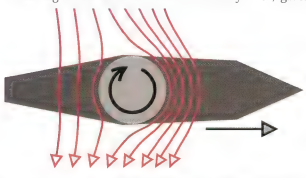
The 14-cylinder, turbocharged two-stroke diesel behemoth is five storeys tall and weighs 2300 tonnes. It puts out 84.4MW (114,800 hp) – up to 90MW when the motor's waste heat recovery system is taken into account.

This mammoth engine is also claimed to be one of, if not the most efficient engines ever built. Even so, under way, it consumes approx 16 ***tonnes*** of bunker fuel per hour or 380 tonnes per day.

If you could save just 10% of this fuel, that would be a saving of 38 tonnes of fuel each day – or, given a



The Magnus Force (aka Magnus Effect) as it applies to a spinning ball, making the ball deviate from its expected path – left, right and even up and down. Perhaps "Bend it like Beckham" should actually have been "Bend it like Magnus".



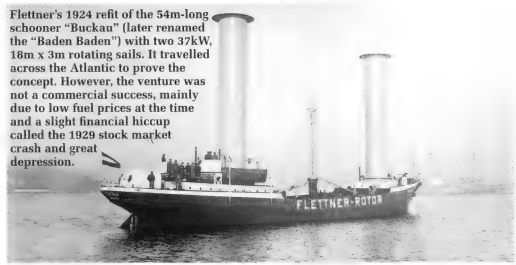
On a spinning but "fixed" object such as a Flettner Sail, those same forces apply – but in this case are transferred to the hull of the ship, making it move in the direction shown. It's not huge – but it's worthwhile!

typical 250-day-per-year "at sea" schedule, nearly 10,000 tonnes per annum. At a minimum cost of AU$400 per tonne (and up to almost AU$750 per tonne in some ports), that would be a fuel saving of at least AU$4 million per annum.

Now *that* would be more than enough to make any ship owner smile!

Incidentally, those cost figures apply to the lowest-grade "IFO380" bunker fuel available (ie, highest sulphur content @ 3.5%).

If the ship is forced to use "MGO" grade bunker fuel (1.5% sulphur) or even "L SMGO" (0.1% sulphur), as is now required in many ports around the world to minimise pollution, you can almost double the costs and the savings.



Flettner's 1924 refit of the 54m-long schooner "Buckau" (later renamed the "Baden Baden") with two 37kW, 18m x 3m rotating sails. It travelled across the Atlantic to prove the concept. However, the venture was not a commercial success, mainly due to low fuel prices at the time and a slight financial hiccup called the 1929 stock market crash and great depression.

What is bunker fuel?

Bunker fuel is actually a generic term given to *any* fuel stored in a ship's bunkers, or fuel storage areas, to power its engines. But most people (ship operators included) understand the term to mean the heavy, residual oil left over after gasoline, diesel and other light hydrocarbons are extracted from crude oil during the refining process.

While some vessels are now being built to use compressed natural gas (CNG) and other fuels, most deep-sea cargo ships, tankers etc typically burn bunker fuel. As noted above, there are various grades of bunker fuel available.

Less pollution, too

It has been said that in one year, a single large container ship can emit pollutants equivalent to fifty million cars (*The Guardian, April 23, 2009*). Or conversely, 15 of the world's largest ships emit as much sulphur oxides (SO_x) as ALL of the planet's 760 million cars!

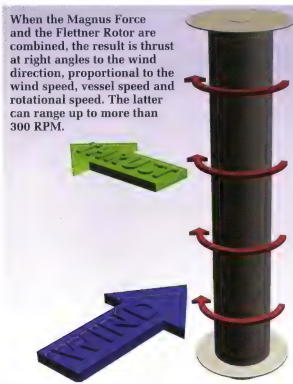
With governments around the world getting tougher on "big polluters", it's in the ship operator's interests to play ball.

For this reason, many ships switch from IFO380 bunker fuel to MGO or even L SMGO fuel as they enter ports or sail close inshore. At sea, it's usually a case of "out of sight, out of mind."

The world's 90,000 vessels emit some 20 million tons of SO_x each year – one large ship can account for more than 5000 tonnes on its own.

Naturally, ship's captains and engineers take all steps possible to minimise fuel use anyway – they usually don't run the engines at maximum speed, for example – but we are talking about a means of saving huge amounts of fuel while maintaining vital schedules.

Hence the interest in the Flettner Rotating Sail. Savings of 7-10% have already been demonstrated and some proponents are claiming theoretical savings of up to 30% (though Norsepower, the main players in the game, claim up to 20%). Try plugging even 20% savings into the figures



When the Magnus Force and the Flettner Rotor are combined, the result is thrust at right angles to the wind direction, proportional to the wind speed, vessel speed and rotational speed. The latter can range up to more than 300 RPM.

The three-rotor ship "Barbara" in Barcelona harbour, 1927. It suffered the ignominy of being sold and having its three rotors removed, converting to standard propulsion! https://commons.wikimedia.org/w/index.php?curid=48364872

The four 27m x 4m Flettner Sails on the E-Ship 1, a 13,000t RoLo cargo ship that made its first voyage with cargo in August 2010. The ship is owned by the third-largest wind turbine manufacturer, Germany's Enercon GmbH and is used to transport wind turbine components. Maximum rotor speed appears to be in the order of 310 RPM, though this depends on both ship speed and wind direction/speed. (Courtesy Enercon GmbH).

above and the dollars become even more dramatic.

The Magnus Force

While the owners of the Emma Maersk are not (currently!) considering refitting that ship, they are currently planning to refit one of their large ocean-going tankers with the revolutionary Flettner Rotating Sail propulsion method.

The tanker in question is 240 metres long and by next year will be fitted with two electrically-driven rotating columns (or "spinning sails"). It is the interaction of these rotating columns with the prevailing winds which provide the propulsion.

It's called the "Magnus Force": wind passing the spinning rotor creates an air flow which accelerates on one side, creating a lower pressure, while it decelerates on the opposite side, creating a higher pressure.

In a similar way that a moving aircraft wing provides lift due to higher pressure underneath, the Magnus Force rotating sail provides a force at right angles to the wind direction. Because the rotating sail is fixed to the deck of the ship, this force provides thrust, which is used to take some of the load off the ship's engine(s).

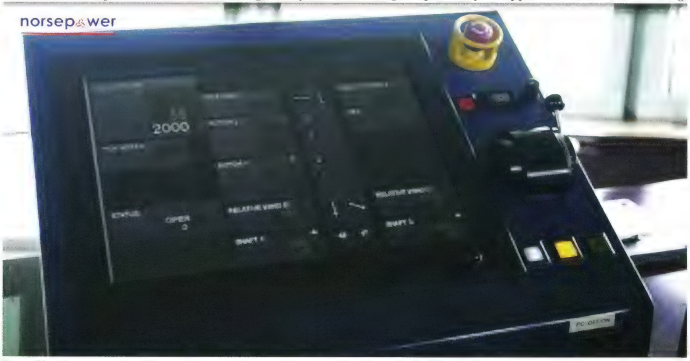
Like a sailing ship, the course of the ship needs to be adjusted for wind direction but unlike a sailing ship, a Magnus rotor ship can sail very much closer into the wind – or "close hauled" – as close as 15° versus about 30°- 45° minimum for sailing ships.

Where did the name "Magnus Force" come from? A German physicist, Heinrich Magnus who described the effect in 1852, when he was analysing the path of cannonballs.

Curiously, Isaac Newton described the same thing almost 200 years earlier (in 1672) after witnessing tennis balls' flight at Cambridge. Newton also theorised the reason... and was 100% correct. 70 years later (1742) a British mathematician, Benjamin Roberts, explained deviations in the trajectories of musket balls using the same forces. His work led to the "rifling" of barrels to make them spin.

If you're a sportsman using any form of ball, you will almost certainly use the Magnus Force – probably without knowing it – to control the flight of the ball.

You can make it longer (eg, a golf ball with backspin flying further than it should . . . or the opposite, when you slice or hook the ball making it go where you don't want it to!), making it dip before your opponent believes it should (eg,



One of big features of the Flettner Rotor is that, unlike a "sailing" boat, no additional crew are required to run it. Here's the control panel which is on the bridge, alongside other instruments. It even has a "big red button" to stop the rotating sails in an emergency!

A Norsepower artist's impression of the Maersk Magnus, an existing tanker currently being retro-fitted with a pair of Norse Power Flettner rotors. 7-10% fuel savings have been demonstrated; some proponents claim much more – 20% according to Norsepower and others as high as 30%! The roll-on roll-off ferry "Estraden" (see photo on p12) is already fitted with Flettner rotors and is achieving 6%+ fuel savings.

a tennis ball with underspin) or even making it deviate from its probable course (eg, a baseball curving away).

Now at least you know who to curse when you're looking for your ball in the rough!

The Flettner Sail

The spinning sail concept is not new – it is usually regarded as the invention, almost 100 years ago, by a German engineer, Anton Flettner.

(We note that Norsepower's website claims it was actually invented by a Finnish engineer, Sigurd Savonius [more famous for the Savonius Turbine] and later developed by Flettner. But that is the only reference which disagrees with popular knowledge). See siliconchip.com.au/l/aacs

In 1924, Flettner refitted a schooner named the Buckau with two rotating cylinders about 15m high and 3m in diameter, driven by 37kW electric motors. Its maiden voyage was in February 1925 across the North Sea from Danzig (Germany) to Scotland.

It was claimed at the time that the rotors did not give the slightest cause for concern in even the stormiest weather. In 1926 the ship, now renamed Baden-Baden, sailed across the Atlantic via South America, arriving in New York on 9th May.

Another rotor ship, the Barbara, served as a freighter in the Mediterranean between 1926 and 1929.

Despite Flettner's attempts to show shipping companies and even yachtsmen the undoubted advantages of his designs, the Flettner rotor ships were not a commercial success, beaten by (a) the very low cost of fuel, and (b) the stock market crash and depression of 1929.

Indeed, after the Barbara was handed back to its owner (the German Navy) in 1931, they onsold it to a new owner who dismantled its three rotors and used only its engines!

Fast-forward nearly a century

Despite the lack of appeal for early 20th century shipowners for the rea-

In this view, the *Estraden* is docked at the ro-ro terminal in Teesport, UK. The Flettner sails (one forward, one aft) are kept spinning, albeit at a much slower speed, providing the ship with some stability while vehicles driving on or off. At sea, the speed is significantly increased. We've seen figures of 300+ RPM although this has been difficult to verify.

Another artist's impression, the LNG-powered *Viking Grace*, which is owned by Finland's Viking Line and operates between the Finnish port of Turku and Stockholm in Sweden. It is already one of the most environmentally friendly ferries in operation but the installation of a single rotor sail will further reduce fuel burn and emissions, saving an estimated 300 tonnes of LNG consumption each year. The Norsepower rotor sail will be retrofitted during the second quarter of 2018 when one medium-sized unit, 24m in height and 4m in diameter, will be installed. The system will be fully automated so that when the wind is strong enough to deliver fuel savings, the rotor starts spinning automatically.

sons already given, with the price of fuel now hovering at or near record levels, shipowners are once again looking at the Flettner Rotor as a means of saving money.

The German wind-turbine manufacturer Enercon launched a new rotor vessel, *E Ship 1*, in 2008. It entered service in August 2010 and is still in service seven years later, ferrying wind turbines and other equipment, primarily to wind farms being constructed in ocean areas. See siliconchip.com.au/l/aacq

In 2014, the roll-on, roll-off freighter *Estraden* was retro-fitted with two Norsepower Rotors.

The sea trials onboard M/V Estraden, verified by NAPA and supported by VTT Technical Research Centre of Finland, confirm fuel savings of 2.6% using a single small Rotor Sail on the vessel's route in the North Sea.

Later tests show a reduction in fuel consumption of 6.1%.

The Estraden's Rotor Sails are effective 80% of sailing time, giving 460kW average propulsion boost and 1.5MW peaking for 10% of time.

Norsepower forecasts savings of 20% for vessels with multiple, large rotors travelling on favourable wind routes. See siliconchip.com.au/l/aacr

The Flensburg University (Germany) has made a rotor-driven catamaran called *Uni-Cat* – there's a video of a catamaran on the Nile River at siliconchip.com.au/l/aaco

There's also another video explaining the Flettner sail advantages on a coastal freighter at siliconchip.com.au/l/aacp along with several other interesting videos on various aspects of Flettner and the Magnus force.

You'll find a huge number of other refences to the Magnus force and Flettner Rotary Sail on the net.

Rotor ship components

Norsepower Rotor Sails are available in three sizes with heights of 18, 24 or 30 metres and diameters of 3, 4 and 5 metres respectively.

The optimal number and size of Rotor Sails are based on the size, speed and operating profile of the target vessel.

The essential parts of the Rotor Sail system are:

- The Rotor Sails themselves, which deliver the forward thrust. Depending on space available and operational requirements, there can be anywhere from one to four (or even six) rotors.
- A suitable mounting location on the ship's deck. Cranes and cargo handling equipment do not normally create excessive turbulence but they must not interfere with rotor sail operation (and vice versa).
- A control panel (usually mounted on the bridge), which gives the crew full control of the operation and performance of the Rotor Sails.
- Wind & GPS sensors, which provide the automation system with real-time wind speed and direction information as well as ship speed and course data to optimise the performance of the Rotor Sails.
- An electrical power supply from the ship's low voltage network to each Rotor Sail. (Remember that low voltage is defined as up to 1000VAC or 1500V DC).

Conclusion

So will it happen? Will we see ferries, container ships and supertankers on the high seas with these spinning columns providing fuel savings and cutting exhaust pollution?

With the successful trials of Flettner Rotors undertaken in Europe (especially) in recent years, it is highly likely that the answer will be yes!

There is other technology out there, much of it involving the wind – giant kites and conventional sails are also being trialled right now.

Or it could perhaps be an as-yet unknown breakthrough which the world's shipping will latch onto.

But one thing is for sure: with ever-rising fuel prices and "green" pressure, something will change! SC

Acknowledgement: much of the information and photographs in this feature courtesy of Norsepower Oy Ltd. For more information, visit their website: www.norsepower.com

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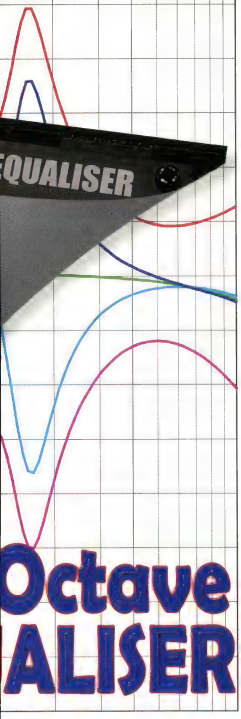
High performance 10
STEREO GRAPHIC EQ

This stereo graphic equaliser is very compact and quite cheap to build. However, it has the performance to match full-blown commercial models which are far more expensive. As well, it can used in a wide range of applications from AC or DC supplies.

It is a very long time since a graphic equaliser has been published in SILICON CHIP – way back in 1989, in fact. The Studio Series 32-Band mono equaliser appeared in March and April 1989 and the Studio Series 20-band stereo equaliser in August and September 1989.

Both these designs have been unobtainable for many years and we have not thought to revise them because of the high cost of the rack-mounting chassis and the multi-slotted screen printed and black anodised front panels which are really too expensive to make such a project economically viable.

This new graphic equaliser was prompted by a reader's suggestion to revise our 3-band Parametric Equaliser from the July 1996 issue, since the kit for that project has also now been discontinued. However, when we looked at updating the design we were also conscious that parametric equalisers can be quite confusing to use – you never quite know how to vary the controls to obtain a desired effect.



Performance of prototype

Gain:	Unity
Input signal with no clipping at max boost:	up to 2.3V RMS
Maximum input signal with flat response:	up to 9.25V RMS; 4.5V RMS with single 15V supply
Frequency reponse (flat):	+0.25,-0.75dB
	10Hz-60kHz (see Fig.1)
Maximum boost:	±12dB (see Fig.1)
Signal-to-noise ratio:	-96dB unweighted with respect to 2V RMS
Total harmonic distortion plus noise:	<0.002%, 20Hz-20kHz, 22kHz bandwidth; typically 0.0016% (see Fig.2)
Channel separation:	>-60dB 20Hz-20kHz, 90dB @ 1kHz (see Fig.3)
Input impedance:	100kΩ // 100pF
Output impedance:	470Ω
Supply current:	55mA typical; 110mA maximum

By JOHN CLARKE

By comparison, graphic equalisers are much more intuitive – you can see which bands you are boosting or cutting and it is quite easy to repeat the settings after a particular listening or recording session. Used carefully, a graphic equaliser can make a considerable improvement to overall sound quality.

It is able to smooth out the frequency response of the reproduced sound, cure peaks, dips or lumps in a loudspeaker's response or simply subtly change the program's tonal quality to your liking.

This 10-octave unit uses an individual slider potentiometer for each octave, giving you far more detailed control than is possible with simple bass and treble controls. And of course, the settings of the slider potentiometers provide a visual graph of the equaliser adjustments with the centre position providing a flat response in the respective octave, ie, no cut or boost.

A slider adjusted above centre shows the level of boost and a slider below centre shows the level of cut. This is why it is called a "graphic" equaliser.

Compact design

Our new 10-Octave Graphic Equaliser is very compact and can be used as a stand-alone unit or incorporated into existing equipment.

So having decided to produce a new design for a graphic equaliser, we had to concentrate on the problem of reducing the cost, particularly that of the metalwork, the large and complicated PCB with all those op amps and gyrator components, and finally all those expensive slider controls. Yesteryear's approach was not going to work.

The slider control was an easy choice, even though it is a bit of compromise. Compact ganged sliders with a 45mm travel and a centre detent are now readily available at low cost and their plastic actuators mean that multiple knobs are not needed. By using ganged sliders, we have been able to drastically reduce the cost and the size of the PCB.

So what was the compromise? The sliders we have selected are linear types with a value of 10kΩ and a centre detent. However, for the best noise and distortion performance we would have preferred a value of 50kΩ. Further, we would have also preferred sliders with a 4BM taper instead of a linear resistance characteristic.

The 4BM taper, as used in our 1989 designs (specially sourced by Jaycar Electronics at the time), has a log/antilog resistance taper; log in one direction, antilog in the other.

If we had gone to the trouble of sourcing special 50kΩ 4BM slider pots, though, the final design would have been very expensive to build.

Suffice to say that we have been able to get the performance up to or better than CD standard, so the compromise is quite satisfactory.

Naturally, we are using a double-sided, plated-through PCB with the 10 ganged sliders on one side and all rest of the components on the other side (pretty closely packed).

However, it is not a hard board to assemble. First, most of the resistors and some of the capacitors (all with a

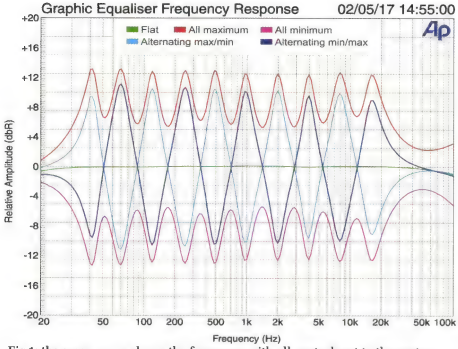


Fig.1: the green curve shows the frequency with all controls set to the centre position, giving a ruler flat response which is only 1dB down at 10Hz and 100kHz. The red and mauve curves show the response with all sliders in the maximum boost setting and all in the maximum cut setting. Finally, two blue curves show the sliders alternately set for maximum boost and cut and these show the effective octave width of each band.

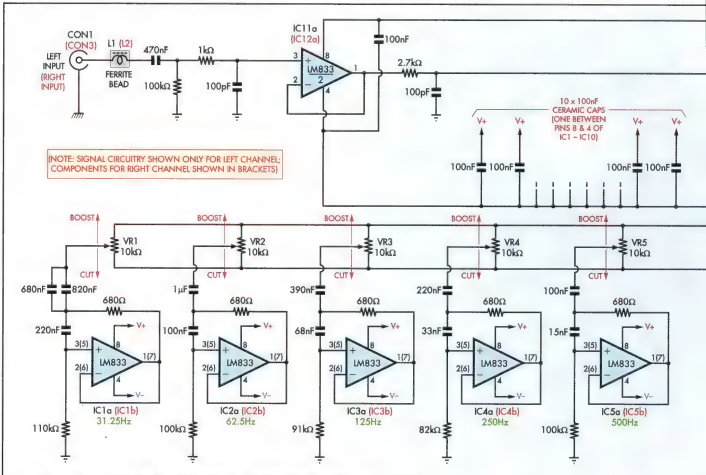
value of 100nF, used as supply bypass capacitors) are reasonably sized (easy to solder!) surface-mount components. The rest of the components are easy to solder through-hole types.

Furthermore, all the SMD resistors are clearly labelled with their values; OK, you will need keen eye-sight, a magnifying glass or spectacles! And the SMD capacitors all have the same 100nF capacitance so you don't need to worry about identifying those.

All the rest of the capacitors are normally-sized MKT polyesters. There are 13 low-noise LM833 op amps and again, to keep the PCB size in bounds, we have used surface-mount types. However, they have a pin spacing of 1.27mm so they are quite straightforward to mount in place.

So the combination of 10 ganged sliders and a double-sided PCB with a mixture of surface-mount and through-hole components results in a compact assembly and avoids a large, expensive PCB.

But what about the problem of the expensive metalwork and a precision



10-OCTAVE STEREO GRAPHIC EQUALISER

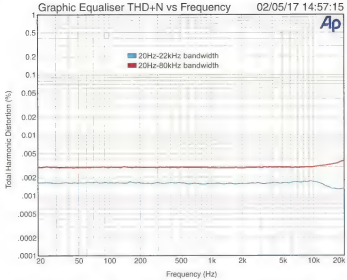


Fig.2: the harmonic distortion performance is limited by the residual noise "floor" of the crucial gain stage in the circuit. The actual harmonic distortion is much lower.

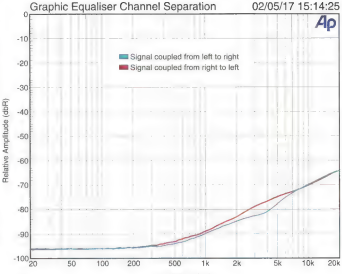


Fig.3: the channel separation of the graphic equaliser and the two curves show that the separation between the channels is almost perfectly symmetrical.

machined, screen-printed front panel with all those slots?

Well, we have dispensed with metalwork altogether!

The front panel is a black screen-printed PCB with precision milled slots – it looks great. And following our recent practice with smaller projects, the case is made of black acrylic which slots together very easily. It looks neat and can be used as a free-standing unit or as part of a larger installation.

If you decide to build the Graphic Equaliser into a larger piece of equipment such as an amplifier or recording console, you probably don't need the acrylic case. You can simply mount the unit in a rectangular cut-out, with the

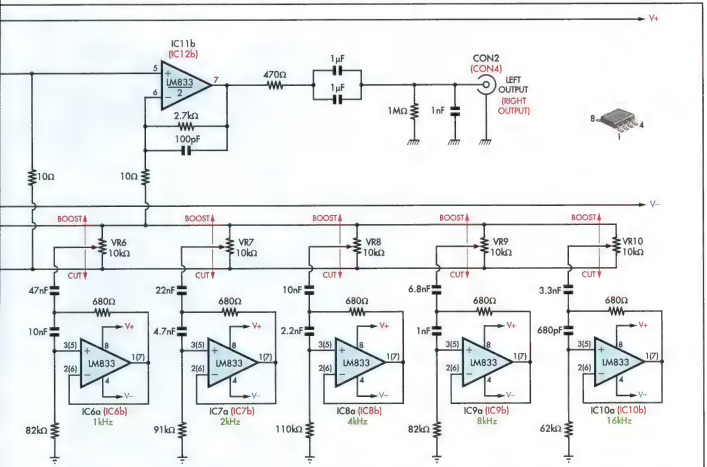


Fig.4: this circuit shows only the left channel – the right channel is identical apart from the IC numbers (shown in brackets).

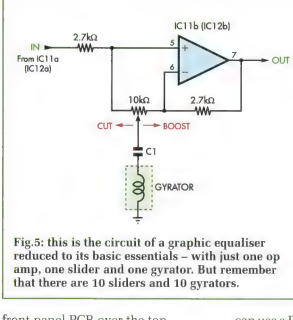


Fig.5: this is the circuit of a graphic equaliser reduced to its basic essentials – with just one op amp, one slider and one gyrator. But remember that there are 10 sliders and 10 gyrators.

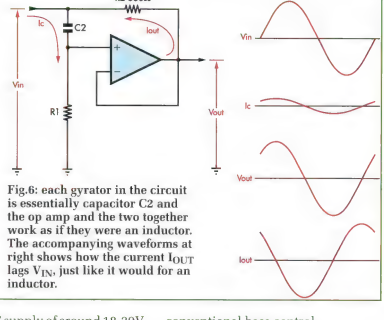


Fig.6: each gyrator in the circuit is essentially capacitor C2 and the op amp and the two together work as if they were an inductor. The accompanying waveforms at right shows how the current I_{OUT} lags V_{IN}, just like it would for an inductor.

front panel PCB over the top.

All the components are on the one PCB and there is no external wiring apart from the supply leads from the on-board connector. Even the RCA input and output sockets are directly soldered onto the PCB. What could be simpler?

Typical applications

Our new Graphic Equaliser can be connected to a stereo amplifier or receiver in several ways. First, it can be connected in the "Tape Monitor" loop that's still provided on most amplifiers and receivers.

Alternatively, the equaliser may be connected between the preamplifier and power amplifier. Some home theatre/stereo receivers include pre-out/in connectors for this purpose.

If you only have a single sound source that has line level output level (anywhere between 500mV and 2V RMS) then the equaliser input can be connected to that source output and the equaliser output connected to the amplifier input.

For sound reinforcement use, you can connect the equaliser between the sound mixer output and amplifier input. In that case, connectors other than the RCA types maybe required and you may need to add a balanced input and balanced output converter on each channel. We published a suitable project to do this in June 2008. See siliconchip.com.au/l/aacv

Power supply options

There are three supply options; you can use a DC supply of around 18-20V, a 15-16VAC plugpack supply or a centre-tapped mains powered 30VAC transformer (or equivalent supply rails in a power amplifier, mixer desk etc).

Performance

The overall performance is summarised in a separate panel and a number of graphs. Fig.1 has a number of coloured response curves. The green curve shows the frequency with all controls set to the centre position, giving a ruler flat response which is only 1dB down at 10Hz and 100kHz.

The red and mauve curves show the response with all sliders in the maximum boost setting and all in the maximum cut setting. Finally, two blue curves show the sliders alternately set for maximum boost and cut and these show the effective octave width of each band.

Note that you would never use a graphic equaliser in these extreme settings – the sound quality would be just weird. Instead, you would normally use comparatively small boost and cut settings for the sliders.

For example, if your loudspeakers are a touch too bright in the 4kHz region, you might apply a slight amount of cut to the respective slider. You could not do this with a normal treble tone control because it would drastically impact the higher frequencies.

Or if you wanted to lift the bass response below 60Hz, you could apply a significant amount of boost on the 31Hz band and get a much more subtle effect than would be possible with a conventional bass control.

We stated that the overall performance was effectively CD-standard and that is backed up by the figures for signal-to-noise ratio and harmonic distortion. Fig.2 demonstrates that the harmonic distortion performance is limited by the residual noise "floor" of the crucial gain stage in the circuit (that of IC11b & IC12b).

In fact, the actual harmonic distortion is well below our quoted figure of around .0016% (typical) but is masked by the residual noise. Suffice to say that the harmonic distortion of this circuit is better than can be achieved by CD and DVD players, so it will not adversely affect the sound quality of signals from such sources.

Finally, Fig.3 shows the channel separation of the graphic equaliser and the two curves show that the separation between the channels is almost perfectly symmetrical.

Circuit details

Fig.4 shows the full circuit of the left channel of the new 10-Octave Stereo Graphic Equaliser. The right channel is identical. The IC numbering and pin numbers for the right channel are shown in brackets. We have used dual low-noise/low-distortion LM833 op amps throughout for high performance.

Before going into the detail of the circuit, let us discuss the operating principles of a typical graphic equaliser.

The overall circuit is effectively an input buffer amplifier, op amp IC11a,

Another view of the completed 10 Octave Stereo Graphic Equaliser in its laser-cut black acrylic case. No knobs are used – the actuators on the slider pots are quite sufficient.

followed by a non-inverting op amp stage, IC11b, with the 10 slider potentiometers connected in parallel inside its feedback network. Connected to the wiper of each 10kΩ slide potentiometer is a series-resonant LC circuit; one for each octave band.

Inevitably the story is much more complicated than this because there are no inductors in the tuned LC resonant circuits. Close tolerance, low distortion inductors are very expensive and bulky, as well as being prone to hum pickup.

Therefore all graphic equalisers designed over the last 50 years or thereabouts use gyrators which are an op circuit which performs just like an inductor and can be connected to a capacitor to provide a series resonant circuit.

Series-resonant circuit

So let's break down the graphic equaliser circuit to show just one op amp and one 10kΩ slider and one series-resonant circuit, as shown in Fig.5. Remember that there are actually 10 resonant circuits but in order to simplify matters, we will only consider one.

In the simplest case, the 10kΩ slider control is set to its centre setting. In this condition, the op amp stage has unity gain and a flat frequency response and the series resonant circuit hanging off the wiper has no effect, because whatever its impedance at a particular frequency, it affects the signals at the inverting and non-inverting inputs (pins 5 and 6 here) equally.

When the slide pot is set to the boost end, the negative feedback from the output pin tends to be shunted to ground by the low impedance of the series tuned circuit at frequencies that it is resonant.

Since its impedance is high at all other frequencies, this means that the feedback is only reduced over the narrow band centred around the resonance of the series tuned network. So frequencies in that band will be boosted while others will be unaffected.

When the slider is set to the other extreme, to "cut", the negative feedback is at a maximum and the series tuned circuit actually tends to shunt input signals in its resonant band to ground. This results in a reduction of gain for the frequencies at or near the resonance of the series tuned network.

As you would expect, the amount of boost or cut is proportional to the slider settings, so intermediate settings give an intermediate level of signal boost or cut.

Note that the circuit of Fig.5 does not show an inductor in the series resonant circuit; it shows the equivalent component, a gyrator (mentioned above).

Gyrators explained

Fig.6 shows the circuit of a gyrator made with an op amp. It effectively transforms a capacitor into an inductor. In an inductor, the current lags the voltage (ie, the current is delayed in phase by 90°) while in a capacitor, the voltage lags the current (by 90°), as it charges or discharges.

Another way to explain this is that if you apply a large voltage step across a capacitor, a very high current flows initially which tapers off as the capacitor charges up to the new voltage.

By comparison, if you apply a large voltage step to an inductor, at first the current flow remains the same as it was before, while the inductor's magnetic field charges but over time the current flow builds as the magnetic field density increases.

To understand how the gyrator circuit behaves like an inductor, consider an AC signal source, V_{IN}, connected to the input of Fig.6. This causes a current to flow through the capacitor and through the associated resistor R1.

The voltage impressed across R1, as a result of the capacitor current I_C, is fed to the op amp which is connected as a voltage follower (buffer), as its inverting input is connected directly to its output.

The voltage at the output of the op amp thus tracks the voltage across R1. This then causes a current to flow through resistor R2. This current, I_{OUT}, adds vectorially with the input current I_C and the resultant current which flows from the source lags the input voltage.

As far as the signal source is concerned, the gyrator "looks" like an inductor, not like an op amp with two resistors and a capacitor connected to it. The inductance is given by the formula:

$$L = R1 \times R2 \times C2$$

where L is in Henries,
R is in ohms
and C is in Farads.

If you're having trouble understanding how this works, consider again the effect of a large voltage step at the input. Say the input rises suddenly by 1V. This is initially coupled through C2 directly to the op amp and so its output also rises by 1V, keeping the voltage across R2 the same.

Thus the current flow from the input changes very little initially; it is just the current to charge C2 which is normally much smaller than that flowing through R2 (since it's is normally a much lower value than R1).

However, as C2 charges, the voltage across R1 drops and so does the op amp output voltage, causing the current flowing from the input, through R2, to increase up to 1.5mA (1V÷680Ω)

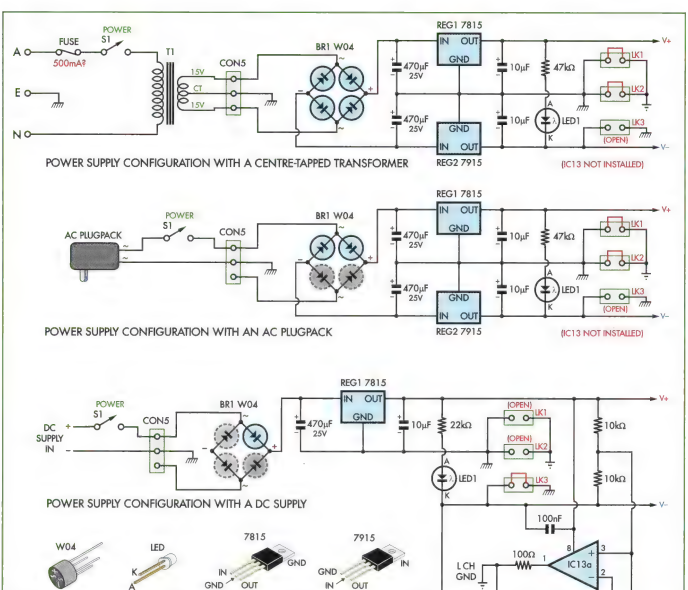


Fig.6: the three power supply variations, which allow you to operate from a mains transformer with centre-tapped secondary (top), a plugpack or similar mains transformer without a centre tap (centre) and a DC supply, such as might be available in existing equipment (bottom). Note that while a BR1 bridge rectifier is used (for convenience) in the two lower supplies only some of its internal diodes are used (unused diodes greyed out) – you could substitute 1N4004 diodes if you wish for those diodes used.

higher than it was initially.

As described above, this behaviour is very much the same as if an inductor was connected instead of the gyrator.

Building a series resonant circuit

To make the tuned LC circuit shown in Fig.5, all we need do is to connect a capacitor in series with the input to Fig.6. The result is a circuit with a dip in its impedance around a specific frequency.

The "Q" of each gyrator is determined by ratio of R1 and R2. Note from the formula above that if you double the value of R1 and halve the value of R2, the simulated inductance does not change. The same is true for the opposite, ie, halving the value of R1 and doubling the value of R2. But the "Q" does change.

If you think about the resonant circuit's impedance like an inverted bell curve, the "Q" relates to the width of the bell. So if you were to increase the value of R2 and proportionally decrease the value of R1, you would reduce the "Q" and thus broaden the bandwidth of the filter.

Note that there are limits to this. You don't want to make the value of R1 too low or else the error current through it could overwhelm the current through R2 and the gyrator would no longer be a very good simulation of an inductor.

You don't want to make the value of R2 too low either, as you will eventually reach a point where the op amp is no longer able to drive such a low load impedance and it will run into current limiting.

And changing the value of R2 also affects the minimum impedance of the resonant circuit which may require changes to other circuit components

to avoid reducing performance.

The value of series capacitor C1 also controls the "Q"; you can change the value of C1 without affecting the centre frequency as long as you change the value of the simulated inductor so that the product remains the same (by changing any of R1, R2 or C2).

Higher values for C1 result in lower "Q" and vice versa. However, adjusting the "Q" with R1 and R2 is generally easier.

The values in our circuit set the bandwidth of each slider to approximately one octave. You can see the degree of overlap provided from the red and mauve curves in Fig.1.

We could have provided more overlap by increasing the values of R2 in our circuit, and reducing the R1 values (which differ for each band) proportionally, however this would also increase the interaction between adjacent bands.

Back to the equaliser

So remember that we have one op amp buffer stage IC11b, with 10 slider pots connected inside its feedback loop. The wiper of each slider is connected to one of the series-tuned circuit described above. Each is tuned to a frequency that is double that of the last, to provide octave bands.

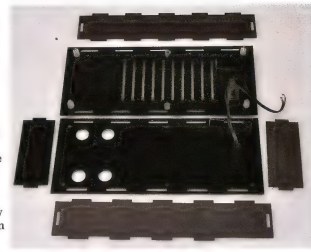
Refer to the main circuit diagram in Fig.4. This shows just the left channel of the stereo equaliser, with one gyrator circuit repeated 10 times, with different values for R1, R2 and C2.

Looking at the top left-hand side of the circuit, the input signal is applied to CON1 and passes through a ferrite bead which acts like an inductance to attenuate any radio signals. A 470nF capacitor blocks any DC voltage while a 100kΩ resistor provides a charging path for the that capacitor and "grounds" the signal. An RC filter comprising a 1kΩ resistor and 100pF capacitor provides further high frequency filtering.

Op amp IC11a buffers the input signal, giving it a low impedance, for the following equaliser circuitry comprising IC11b, the sliders (VR1-VR10), IC1-IC10 plus associated components for the gyrators.

The output signal of the graphic equaliser appears at pin 7 of IC11b and this is fed via a 470Ω resistor and a 2μF DC blocking capacitor (using two parallel 1μF capacitors) to the output at CON2. The 1MΩ resistor to ground sets the DC level for the output signal

Here's a sneak peek at the laser-cut acrylic flatpack "case" mentioned in the text which significantly reduces the cost of building the Graphic Equaliser – and adds to the professional appearance. The pieces slot together to form a very smart-looking case in piano-finish black with white marking. We'll show how this goes together – and how the PCB fits in place – in part two next month.



while the 1nF capacitor shunts any out-of-band high frequency noise to ground.

The 470Ω resistor sets the output impedance of the equaliser, while the 2μF output capacitor and 470nF input capacitor set the low frequency -3dB point of the entire circuit to about 4Hz.

Potentiometer value doesn't affect gain

One thing to note about the equaliser circuit which may not be obvious is that if you changed the potentiometer resistances to another value, the output level and frequency response would not change but the noise performance might.

Imagine that all the slider pots are centred for the moment and consider each tuned circuit as having a low impedance (since white noise exists over a wide range of frequencies). This means that half of each slide pot is effectively connected between pin 5 of IC11b and ground (with a 10Ω resistance in series). The impedance of ten 5kΩ resistances in parallel is 500Ω; add the 10Ω to get 510Ω.

This 510Ω forms a divider with the 2.7kΩ resistor at the output of IC11a, providing a signal attenuation of 0.16 times (510Ω ÷ [2.7kΩ + 510Ω]). Now, IC11b has a 2.7kΩ feedback resistor and it also forms a divider with the other half of all the slide pots in parallel, again 2.7kΩ/510Ω.

But because it's in the feedback loop, it provides gain, not attenuation; 6.3 times in fact.

Since 0.16 x 6.3 = 1.0, therefore, the gain from input to output of the equaliser is unity. If you change the potentiometer values to say 50kΩ, then you end up with an attenuation of 0.48 (2.5kΩ ÷ [2.7kΩ + 2.5kΩ]) and a gain of 2.08 times (2.7kΩ ÷ 2.5kΩ + 1), again giving 0.48 x 2.08 = 1.0. So the gain is still unity.

So the lower the slide pot values, the more the input signal is attenuated and the more gain is applied later to compensate.

Unfortunately, though, that gain also applies to any noise in the circuit. Thus, 10kΩ pots result in three times (6.3 ÷ 2.08) as much noise as if we were using 50kΩ pots, or a degradation in signal-to-noise ratio of around 9.5dB.

But as we said earlier, 50kΩ slide pots with a centre detent are more expensive and harder to get. As the performance with 10kΩ pots is pretty good, we feel that this is a reasonable compromise.

Power supply options

As already noted, there are three power supply options and these are depicted in Fig.7.

You can use a centre tapped 30V transformer, a 15-16VAC plugpack or a DC supply of up to 20V. There are two ground/earth connections shown on the circuit with different symbols for each.

One is the ground for the power supply, signal inputs and signal outputs. The second is the ground reference signal for the op amp circuitry. The two are connected directly together when using a ±15V (AC-derived) supply. This is shown in the dual supply section of the circuit, where LK1 and LK2 connect the grounds together.

The power supply ground is connected to the centre tap of the transformer and is also the ground for both REG1 and REG2. These regulators provide the +15V and -15V supply rails and receive voltage from the full wave rectifier (BR1) and the raw rectified DC

Parts list – Graphic Equaliser

1 PCB coded 01105171, 198 x 76mm (Silicon Chip online shop Cat SC4279)
1 front panel PCB 198 x 76mm (Silicon Chip online shop Cat SC4280)
1 Acrylic case and hardware to suit (optional)
10 dual ganged 45mm travel 10k linear slider pots (VR1-VR10)
2 vertical PCB mount white RCA sockets (Altronics P0131) (CON1,CON2)
2 vertical PCB mount red RCA sockets (Altronics P0132) (CON3,CON4)
1 3-way PCB mount screw terminals with 5.08mm spacing (CON5)
2 5mm long ferrite RF suppression beads (L1,L2)

Semiconductors
12 LM833D SOIC-8 op amps (IC1-IC12)
1 5mm high brightness blue LED (LED1)

Capacitors (through hole 5.08mm pitch, all 5% tolerance except for surface mount types)
6 1µF MKT polyester
2 820nF MKT polyester (Rockby Electronics #32693)
2 680nF MKT polyester
2 470nF MKT polyester
2 390nF MKT polyester
4 220nF MKT polyester
4 100nF MKT polyester
12 100nF X7R ceramic ^
2 68nF MKT polyester
2 47nF MKT polyester
2 33nF MKT polyester
2 22nF MKT polyester
2 15nF MKT polyester
4 10nF MKT polyester
2 6.8nF MKT polyester
2 4.7nF MKT polyester
2 3.3nF MKT polyester
2 2.2nF MKT polyester
4 1nF MKT polyester
2 680pF MKT polyester
6 100pF ceramic

Acrylic case parts
1 Acrylic case 211 x 89 x 40mm
1 SPST rocker switch (Altronics S3210, Jaycar SK0984) (S1)
1 panel mount 2.1 or 2.5mm DC socket to suit supply plug
1 15mm length of 5mm heatshrink tubing
1 20mm length of 10mm heatshrink tubing
4 6.3mm long M3 tapped spacers
4 25mm long M3 tapped spacers
4 3mm nylon washers
4 15mm long M3 screws
6 10mm long M3 screws
2 M3 nuts

Resistors (0.25W 1%; # = metal film; ^ = 1206 thin-film surface mount)

2 1MΩ#	2 100kΩ#	4 2.7kΩ#	2 1kΩ#	2 470Ω#	4 110kΩ^
4 100kΩ^	4 91kΩ^	6 82kΩ^	2 62kΩ^	20 680Ω^	4 10Ω#

AC supply
2 2-way pin headers with 2.54mm spacings (LK1, LK2)
2 shorting blocks
1 W04 1.2A bridge rectifier (BR1)
1 7815 positive 15V regulator (REG1)
1 7915 negative 15V regulator (REG2)
2 470µF 25V PC electrolytic
2 10µF 16V PC electrolytic
1 47kΩ resistor^

DC supply
1 2-way pin header with 2.54mm spacing (LK3)
1 shorting block
1 LM833D SOIC-8 op amp (IC13)
1 W04 1.2A bridge rectifier (BR1); 1N4004 diodes may be substituted (see text)
1 7815 positive 15V regulator (REG1) or 7812 12V; or no regulator (see text)
1 470µF 25V PC electrolytic
1 100µF 16V PC electrolytic
1 10µF 16V PC electrolytic (not required if REG1 not used)
1 100nF X7R ceramic ^
1 22kΩ resistor^
2 10kΩ resistor^
2 100Ω resistor^

is filtered using 470µF capacitors. One capacitor is for the positive supply and the other for the negative supply.

Power LED (LED1) lights with voltage applied between the +15V and -15V supplies and is supplied current via a 47kΩ resistor.

You can use a 15-16VAC plugpack instead of a centre-tapped transformer. This connects to CON5 between the 0V and an AC terminal of CON5. The bridge rectifier then half-wave rectifies the input AC voltage. Two of its internal diodes are thus unused, and are shown shaded. The resulting ±15V supply rails then run the circuit.

For a DC supply, the positive voltage is applied to one of the (normally) AC inputs and the negative connection to the 0V terminal of CON5. Bridge rectifier BR1 then operates as if it were a diode, providing reverse polarity protection (the other three internal diodes are unused and thus are shaded in Fig.6).

For input voltage above about 18V, you can use a 15V regulator for REG1, as with the AC supply options. If the input DC supply is less than this, use a 12V regulator (7812). With a supply voltage below 15V, REG1 should be left out, and its input and output terminals shorted, so that the external supply runs the circuit directly (but via BR1).

When using a DC supply, there is no negative rail available and so REG2 is left off. LK3 is fitted to connect the V- supply rail to the negative side of the external supply (ie, 0V). LK1 and LK2 are left open. As there is no negative rail, all signals to the op amps now must be biased at half supply so that there will be a symmetrical signal swing. The half supply voltage rail becomes the op amp signal grounds.

This is provided by additional op amps IC13a and IC13b. A half supply rail is derived from two series 10kΩ resistors across V+ and V- that are bypassed with a 100µF capacitor, to remove supply ripple.

Op amps IC13a and IC13b buffer this half supply for the two channels. The signal grounds are separate to minimise crosstalk between channels. IC13 can be left off when using an AC supply.

Construction

That's it for this month. Next month we will go over the details for assembling the PCB and case, putting it all together and getting it up and running. sc

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Device:LPS-50-15
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Tolerance: +/- 2%
Ripple & Noise:80mV/p-p
Efficiency: 84%
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Cold Start Inrush : 35A
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Manufacturer: Meanwell

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12VDC Axial Dual Ball Bearing Fan

Device:FD1751B12W1-61
Brushless Axial Fan
Voltage: 12VDC 20W
Bearing Type :Dual Ball Bearing
Airflow CFM:215
RoHS:Yes
Noise Level(dBA):55
Size:170 x 150 x 50mm
Manufacturer:CoolTron

$6.00

#44863

12VDC 2A Mini Regulated P/ Supply

Input: 240VAC
Output: 12VDC 2Amps
Connections: Solder
Size: 34 x 83mm
Overall height: 22mm
Model: SW2412002

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Silicone Safety 4mm Test Male - Male Leads

Device:2355-IEC-120
Length:1.2m Safety Patch Cord
2.5mm2 PVC
Type 1, 1000V CAT IV
Current 36A
Manufacturer:
Electro PJP (France)

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Device: MCBB400
Pitch : 2.54mm
Terminal Strips : 300 Tie-point
Distribution Strips : 100 Tie-point
Rated Volt./Curr. : 300V/3 to 5A
Wire Range : 29AWG to 20AWG

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The applicator has a precise squeeze action for a controlled delivery.
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Device:CKL-12ATW1
* Tubular Key
* SPDT (Change Over Switch
* Solder Contacts
Rating:250VAC 3A
Hole size: 19mm
Overall Length: 40mm
Manuf.:NKK Switches (USA)

$3.00 ea.

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8 x 3mm Rare Earth Magnets (Pack of 10)

Rare Earth Magnets
External Diameter:8mm
Height 3mm
Magnet Type: Button
Material :Neodymium Iron Boron
Manufacturer:Duratools

#41729

$2.00

6mm Stud Copper Lug 2.5mm Cable

Device:DX 2.5-6
* Heavy Duty Crimp Lug
* Electro Tinned
* Bell Entry
* Copper Tube Double Annealed
Suits: 2.5mm2 cable
Overall length: 21mm
Manufacturer:Davico

#43769

$4.00
(Pack of 100)

150V 60A 320W N-CH FET

Device:IRFB52N15D
Polarity:N-CH
Vds:150V
Ids:60A
Pd:320W
Rds On Max: .032 Ohm
Package: TO-220AB
Manuf.:International Rectifier

#44665

$0.20
(min 50)

7 Colour Cycle Auto Slow Sequence 5mm LED

Device:BK56RGBSC-S
* Built In Controller Chip
* Resistor Required To Limit Current To 20mA
* Lens:Water Clear
Manufacturer:HI Led

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12V 60 x 60 x 25mm Brushless Fan

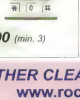
FP-108F/DC -S1
Air Flow: 38.5CFM
Speed: 7000 RPM
Noise Level: 46dBA
Frame & Impeller:
Sleeve Bearing and Ball Bearing
Manuf.Commonwealth (Taiwan)

#43742

$1.50 *(min. 3)*

3 x 4 Matrix Keypad

Device:AK-207-N-WWB
Overall Size: 56mm x 76mm
Colour:cream
Manufacturer:Jameco



#32346

$1.00 (min. 3)

Stereo Speaker Connector-4mm Banana Socket

Device:WP4-10C
Speaker Connector Plate
Rated load:100V 3A/100V 1.5A
Die. strength:AC500V(50Hz)/min
AWG#24-#16
Size(mm):43x19
Manufacturer:Zuanbao

#45036

$0.40
(min. 10)

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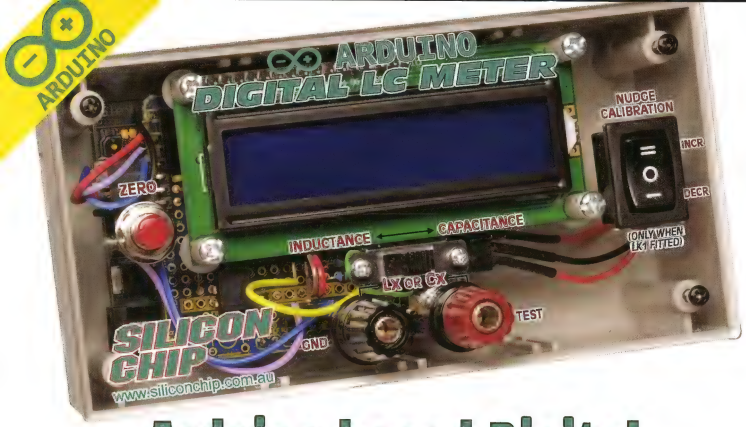


Arduino-based Digital Inductance/Capacitance Meter

Do you ever need to check or confirm the values of inductors or capacitors? This Arduino-based LC meter will give you a digital readout and can even measure parasitic inductance or capacitance present in a circuit. It's much more accurate than most DMM-based LC meters.

Many digital multimeters (DMMs) have capacitance ranges but they are not normally accurate for values below about 50pF. And those few DMMs that can measure inductance are often not very good at measuring inductance in the range of 1-100µH – those that are typically used in audio and RF circuits.

An inductance meter with a 10µH resolution (typical for DMMs) isn't very helpful if you want to wind a choke of say 6.8µH, for an amplifier output filter.

Professionals tend to rely on digital LCR meters for these types of measurements. They allow you to measure almost any passive component quickly and automatically, often measuring not just their primary parameter (like inductance or capacitance) but one or more secondary parameters as well. However, many of these you-beaut instruments also carry a hefty price tag, keeping them well out of reach for many of us.

Fortunately, thanks to microcontroller technology, much more affordable digital instruments are becoming available. These include both commercial and DIY instruments like the low-cost unit described here.

By JIM ROWE

Essentially it's an improved version of the PIC-based Digital LC Meter we described in the May 2008 issue of SILICON CHIP. This time, we're basing it around an Arduino Uno or equivalent module.

Main features

Our new Digital LC Meter is compact and easy to build, since the Arduino board comes pre-assembled. It also has a better LCD readout than the previous version. It fits snugly inside a UB3 utility box and you should be able to build it for under $100.

It offers automatic digital measurement of both inductance (L) and

capacitance (C) over a wide range and with 5-digit resolution. Measurement accuracy is better than ±1% of reading over most of the ranges.

It operates from 5V DC, drawing an average current of about 62mA, so it can run from a 5V USB supply (either mains or battery) or from a spare USB port on your PC.

How it works

The meter's impressive performance relies on an ingenious measurement technique developed almost 20 years ago by the late Neil Heckt in the USA.

It uses a wide-range test oscillator and its frequency is varied by connecting the unknown inductance or capacitance you're measuring. The resulting change in frequency is measured by the microcontroller and used to calculate the component's value, which is displayed directly on a small LCD panel.

To achieve reliable oscillation over a wide frequency range, the test oscillator is based on an analog comparator with positive feedback around it, as shown in Fig.1. This configuration has a natural inclination to oscillate, because of the very high gain between the comparator's input and output.

When power (+5V) is first applied, the comparator's positive input is held at +3.3V by the divider formed by the two 100kΩ resistors and the 100kΩ and 4.7kΩ resistors. Initially, the voltage at the negative input is zero because the 10µF capacitor at this input needs time to charge via the 47kΩ resistor.

So with its positive input much more positive than the negative input, the comparator initially switches its output high, to near +5V.

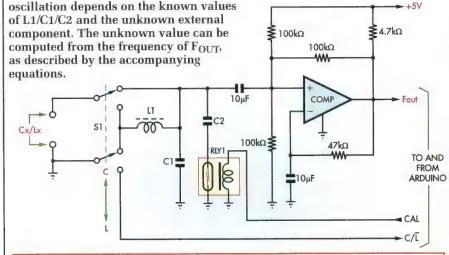
Once it does so, the 10µF capacitor connected to the negative input begins charging up via the 47kΩ resistor and the voltage at this input rises. As soon as it goes above +3.3V, the comparator output switches low and the positive input is brought to 1.67V due to the 100kΩ feedback resistor pulling the 100kΩ divider low.

The low comparator output voltage is also coupled through the 10µF input capacitor to the tuned circuit formed by inductor L1 and capacitor C1. This makes the tuned circuit "ring" at its resonant frequency.

As a result, the comparator and the tuned circuit now function as an oscillator at that resonant frequency. In effect, the comparator functions as a negative resistance across the tuned circuit, to cancel its losses and maintain oscillation. Once this oscillation is established, a square wave of the same frequency is present at the comparator's output and it is this frequency (F_{OUT}) that is measured by the microcontroller.

In practice, before anything else is connected to the circuit, F_{OUT}, will simply correspond to the resonant frequency of the tuned circuit comprising L1, C1 and any stray inductance and capacitance that may be associated with them.

Fig.1: operating principle of the LC Meter. L1 and C1 form a tuned circuit in combination with an external capacitance/inductance connected via S1. Feedback for oscillation is provided by a comparator and the frequency of oscillation depends on the known values of L1/C1/C2 and the unknown external component. The unknown value can be computed from the frequency of F_{OUT}, as described by the accompanying equations.



HOW IT WORKS: THE EQUATIONS

(A) In calibration mode

(1) With just L1 and C1: $F1 = \frac{1}{2.\pi.\sqrt{L1.C1}}$

(2) With C2 added to C1: $F2 = \frac{1}{2.\pi.\sqrt{L1.(C1+C2)}}$

(3) From (1) and (2), we can find C1: $C1 = C2 \cdot \frac{F2^2}{(F1^2 - F2^2)}$

(4) Also from (1) and (2), we can find L1: $L1 = \frac{1}{4.\pi^2.F1^2.C1}$

(B) In measurement mode

(5) When Cx is connected: $F3 = \frac{1}{2.\pi.\sqrt{L1.(C1+Cx)}}$

so $Cx = C1 \cdot \left(\frac{F1^2}{F3^2} - 1\right)$

(6) Or when Lx is connected: $F3 = \frac{1}{2.\pi.\sqrt{(L1+Lx).C1}}$

so $Lx = L1 \cdot \left(\frac{F1^2}{F3^2} - 1\right)$

NOTE: F2 & F3 should always be lower than F1

When power is first applied to the circuit, the microcontroller measures this frequency (F1) and stores it in memory. It then energises reed relay RLY1, which switches capacitor C2 in parallel with C1 and thus lowers the oscillator frequency. The micro then measures and stores this new frequency (F2).

Next, the micro uses these two frequencies plus the known value of C2 to accurately calculate the values of both C1 and L1. The equations it uses to do this are shown in Fig.1. Following these calculations, the micro

Features & specifications

Inductance range:	10nH to 100mH+
Capacitance range:	0.1pF to 2.7µF+ (non-polarised only)
Measurement resolution:	five digits in either mode
Range selection:	automatic
Sampling rate:	approximately one measurement per second
Accuracy (when calibrated):	±1% of reading, ±0.1pF or ±10nH
Supply voltage:	5V DC @ <65mA (including backlit LCD)
Supply type:	USB charger or the USB port on a PC

turns RLY1 off again to disconnect C2, allowing the oscillator frequency to return to F1. The unit is now ready to measure the unknown inductor or capacitor (L_X or C_X).

As shown in Fig.1, the unknown component is wired to the test terminals at far left. It is then connected to the oscillator's tuned circuit via switch S1.

When measuring an unknown capacitor, S1 is switched to the "C" position so that the capacitor is connected in parallel with C1. Alternatively, for an unknown inductor, S1 is switched to the "L" position so that the inductor is connected in series with L1.

In both cases, the added L_X or C_X again causes the oscillator frequency to change to a new frequency (F3). As with F2, this will always be lower than F1.

So by measuring F3 as before and monitoring the position of S1 (which is done via the C/L line), the micro can calculate the value of L_X or C_X using one of the equations shown in the right section of the equations box in Fig.1.

From these equations, you can see that the micro has some fairly solid number-crunching to do, both in the calibration mode when it works out the values of L1 and C1 and in the measurement mode when it must work out the value of L_X or C_X.

Each of these values needs to be calculated to a high degree of resolution and accuracy, using floating-point maths.

Circuit details

The full circuit diagram is shown in Fig.2. It mainly consists of the Arduino microcontroller module and the serial I²C LCD module together with the oscillator circuit we've already introduced, built using an LM311 high-speed comparator (IC1).

The Arduino controls RLY1 to switch calibrating capacitor C2 (1nF) in and out of circuit, via its IO3 pin. Diode D1 is connected across the relay coil to prevent the Arduino's internal circuitry from being damaged by inductive spikes.

The Arduino senses which position L-C switch S1 is in using its IO2 pin, which is pulled high internally when it's not pulled low by S1b (in the L position).

The output of the oscillator at pin 7 of IC1 is taken to pin IO5 of the Arduino via a series 6.8kΩ resistor. It needs to be taken to this pin because this is also the external input pin for the 16-bit timer/counter inside the ATmega328P micro which forms the heart of the Arduino Uno.

As a result, we are able to use the Arduino to easily measure the oscillator's frequency.

The results of the Arduino's measurements and calculations are displayed on a blue back-lit 16x2 alphanumeric LCD module.

This has a serial I²C module fitted, so it can be controlled from the Arduino via its I²C port lines (SCL and SDA).

Its features were fully described in SILICON CHIP March 2017 issue.

Calibration functions

The firmware sketch running in the Arduino is designed to perform its "zero calibration" adjustment just after initial startup.

But pushbutton switch S2 is also provided to allow zero calibration to be performed at any other desired time as well (to allow for temperature drift, for example).

S2 pulls the Arduino's $\overline{\text{RESET}}$ pin (pin 4) down, so that it is forced to reset and start up again, readjusting its zero setting in the process.

LK1 and switch S3 can be used to nudge or tweak the calibration in small increments or decrements, if you have access to an accurate reference capacitor. When LK1 is fitted, pulling input pin IO7 low, the micro will increase

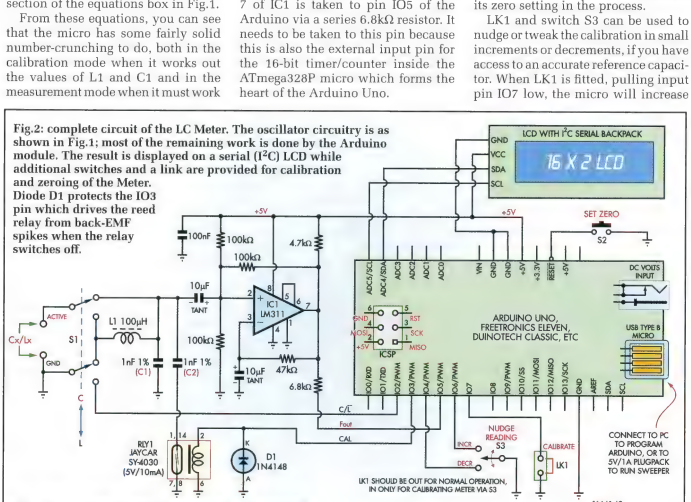


Fig.2: complete circuit of the LC Meter. The oscillator circuitry is as shown in Fig.1; most of the remaining work is done by the Arduino module. The result is displayed on a serial (I²C) LCD while additional switches and a link are provided for calibration and zeroing of the Meter. Diode D1 protects the IO3 pin which drives the reed relay from back-EMF spikes when the relay switches off.

the capacitance reading by about 0.5% each time S3 (a centre-off rocker switch) is pushed to the upper "INCR" position, or alternatively decrease the reading by the same amount if S3 is pushed to the lower "DECR" position.

So the idea is to push S3 in one direction or the other until the reading is correct.

Each time a change is made, the adjustment factor is stored in the Arduino's EEPROM memory, so it's remembered for future sessions. When link LK1 is not fitted, pressing S3 in either direction has no effect at all.

This is a safety feature, to prevent unintended changes to the meter's calibration during normal use. Although this calibration is normally done using a reference capacitor, it also improves the accuracy of inductance measurements.

Construction

There is no custom PCB used for the LC meter's circuitry; instead, most of the added circuitry is fitted on a prototype shield board which simply plugs into the top of the Arduino PCB.

There aren't that many components involved, so it's a straightforward job to wire it up as shown in the wiring diagram, Fig.3.

The only components which are not mounted on the ProtoShield are the serial LCD module, switches S1-S3, the test terminal binding posts and reference components L1 and C1.

As shown in Fig.3 and the photos, these are all mounted on the lid of the UB3 box, which forms the meter's front panel. These off-board components are all linked to the ProtoShield board via short multi-wire interconnection leads and SIL connector plugs and sockets, which are also shown in Fig.3.

You can get an idea of how everything fits together from the internal cutaway diagram of Fig.4, along with the internal photos.

The Arduino module mounts in the bottom of the box via four 9mm long M2.5 machine screws and four M2.5 nuts, with another four M3 or M2.5 Nylon nuts used as spacers.

The ProtoShield is plugged into the top of it. The rest of the meter circuitry connects via the 90° pin headers on the ProtoShield.

Follow the wiring diagram (Fig.3) and internal photos to build the ProtoShield. Start by soldering the components into place where shown

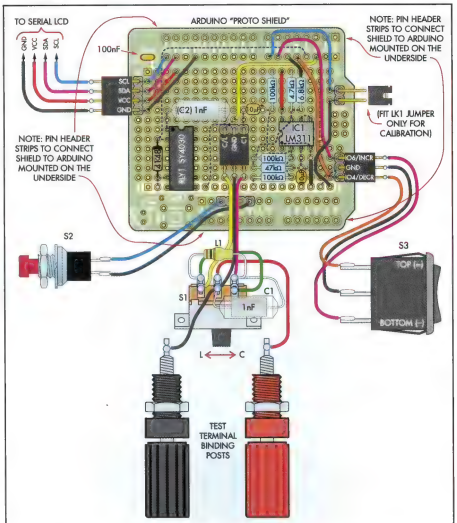
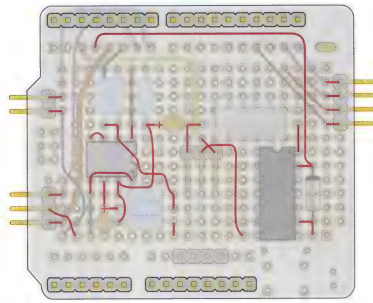
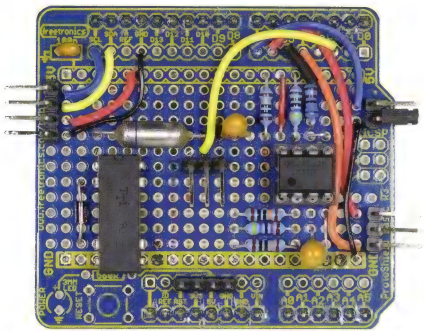


Fig.3: follow these diagrams to fit the components to the ProtoShield and also to wire up all the external connections. Connections made between component pads on the underside are shown below, significantly larger than the 1:1 diagram above, for clarity. These should be made with insulated wire to avoid short circuits.





"Larger than life" photo of the wiring on the top side of the Freetronics Arduino ProtoShield board (actual size is shown in Fig.3, below). This board "plugs in" to the Arduino Uno (etc) board via the rows of pin headers on the underside; the I²C LCD board plugs into the ProtoShield board.

in Fig.3, ensuring you use the correct orientation for polarised components: IC1, diode D1, RLY1 and the two 10µF tantalum capacitors.

Next, add the wiring on the underside, as shown in the underside wiring diagram of Fig.3. Use insulated wire because several of these wires cross over each other.

In cases where adjacent pads are connected, you can simply place a solder bridge between the two pads or alternatively, bend the component leads while fitting them and trim them so that they reach the adjacent pads. For longer connections, use component lead off-cuts, routed carefully to avoid the possibility of shorting anything else, or short lengths of light-duty hookup wire (eg, stripped from a piece of ribbon cable) or bell wire.

Here's our suggested order of fitting the components and wiring the ProtoShield board; check Fig.3 for the exact placement in each case:

1. Fit the four 90° SIL headers.
2. Fit a four-pin vertical header for switch S2.
3. Fit the four SIL pin headers to the underside, along the upper and lower edges of the ProtoShield, which connect it to the Arduino. These comprise a 10-pin header at upper left, two 8-pin headers (one at upper right and the other at lower centre) and a 6-pin header at lower right. Do not fit a 3x2 DIL pin header in the ICSP position at centre right on the ProtoShield board.
4. Fit the 8-pin DIL socket for IC1, with its notched end to the left, then relay RLY1, with its notched end towards the top.
5. Mount the six resistors, the 100nF capacitor and the two 10µF tantalum caps. Note that the last two are polarised, so make sure you fit them with the orientation shown.
6. Fit the 12 insulated wires on the top of the board and any insulated wires required to complete the wiring on the underside. This will require you to strip the insulation from each end by about 5mm or so.
7. Fit diode D1, making sure its end with the cathode band is uppermost and adjacent to pin 2 of RLY1, then plug IC1 into its socket.

Box and lid preparation

There are four holes to drill in the bottom of the box for mounting the Arduino module and two larger holes to cut in the left-hand end for the USB plug and alternative DC power plug.

The locations and dimensions of

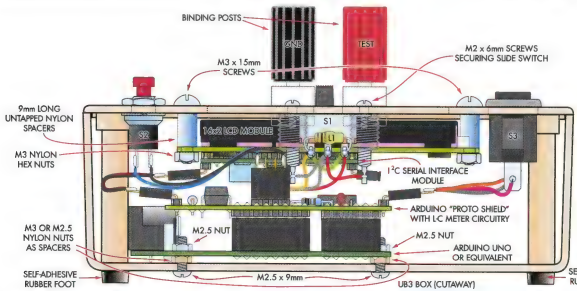


Fig.4: this shows how everything fits together inside the UB3 "Jiffy" box. The Arduino module is attached to the bottom of the case with the proto-board hosting most of the remaining circuitry plugged on top. The three switches, two binding posts and the I²C LCD module are mounted on the lid and connected to the ProtoShield via flying leads.

The Freetronics Eleven (Uno equivalent) board, mounted in the bottom of the case (see drilling template on pages 35 and 36).

all of these holes are shown in Fig.5, the drilling template, while the corresponding information for the holes to be drilled and cut in the lid/front panel are shown in Fig.6.

For best results, start the larger holes with a smaller pilot drill and enlarge with a stepped drill bit, series of larger drill bits or a tapered reamer. Rectangular or other non-round holes can be made by drilling a series of holes, knocking out the centre section and then filing the hole to shape.

We fixed four self-adhesive rubber feet to the underside of the box to protect any surface it's placed on.

Making all the required holes in the lid is rather tedious as there are twelve, including three rectangular cut-outs and two holes with flat edges.

To save time and guarantee a neat result, you can purchase a laser-cut clear acrylic lid (which replaces the lid supplied with the box) from the SILICON CHIP online shop (see parts list).

As the acrylic panel is transparent the lid doesn't need a cut-out to view the LCD. Note that since the 3mm acrylic is slightly thicker than the lid supplied with the UB3 box, depending on the length of the screws that came with it, you may need to use slightly longer self-tapping screws to attach it.

We have also prepared artwork for the front panel, to give it a professional look. You can download this as a PDF file from the SILICON CHIP website.

There are two ways to go here: after you print it, it can be hot laminated, then attach it to the box lid using double-sided adhesive tape or spray glue. After that, you can cut out the holes in the front panel to match those in the box lid using a sharp hobby knife.

Or, for longest life and an even more professional finish, consider fitting the label to the *underside* of the lid – it's more fiddly to fit but doesn't require laminating, nor double-sided tape to hold it in place (the switches and terminals hold it in position; a very light mist of clear spray adhesive will also ensure it stays tight against the lid).

Perhaps it's gilding the lily somewhat but if you can print the label onto clear film, you can see the "works" through the label, as we did with the photo on page 28.

Just make sure you get the right film to suit your type of printer (eg, laser printer or inkjet printer, etc).

Once the lid/front panel is finished, fit switches S1-S3 to it, along with the two test terminal binding posts and the serial LCD module.

Slide switch S1 attaches to the front centre of the lid via two 6mm long M2 machine screws, while switch S2 mounts using the spring washer and nut supplied with it and S3 simply pushes into its rectangular mounting hole until its two barbs spring outwards to hold it in place.

Just make sure that you fit it with the "=" sign on its rocker actuator uppermost (see photos).

The two binding posts are mounted using the mounting nuts and lock washers provided.

Take care doing so, however, as the upper and lower mounting bushes have D-shaped sections which should mate with the matching holes in the lid/front panel.

The serial LCD module mounts under the lid in the top centre position,

Parts list – Arduino-based LC Meter

1 Arduino Uno R3, Duinotech Classic, Freetronics Eleven or equivalent microcontroller module
1 Serial I²C 16x2 LCD module with back-lighting (SILICON CHIP online shop Cat SC4198)
1 Arduino Uno Prototyping Shield (eg, Freetronics SH-Proto-Basic)
1 UB3 "Jiffy" box, 130 x 68 x 44mm
1 laser-cut clear acrylic lid for UB3 box [optional but recommended] (SILICON CHIP online shop Cat SC4274)
4 self-adhesive rubber feet
1 5V/10mA DIL reed relay (RLY1; Jaycar SY4030)
1 100µH axial RF inductor (L1; Jaycar LF1534)
1 DPDT subminiature slide switch (S1; Jaycar SS0821)
1 panel-mount SPST NO momentary pushbutton switch (S2; SP0710)
1 panel-mount SPDT on-off-on momentary rocker switch (S3; Jaycar SK0987)
1 8-pin DIL IC socket
1 40-pin header, 2.54mm pitch
1 40-pin right-angle header, 2.54mm pitch
1 150mm socket-to-socket jumper ribbon cable (Jaycar WC6026)
1 jumper shunt
2 binding posts with integral banana socket (1 red, 1 black)
4 9mm Nylon untapped spacers, 3mm inner diameter
4 15mm M3 machine screws
8 M3 Nylon hex nuts
4 9mm pan head M2.5 machine screws
4 M2.5 hex nuts
2 6mm M2 machine screws (for S1)

Semiconductors

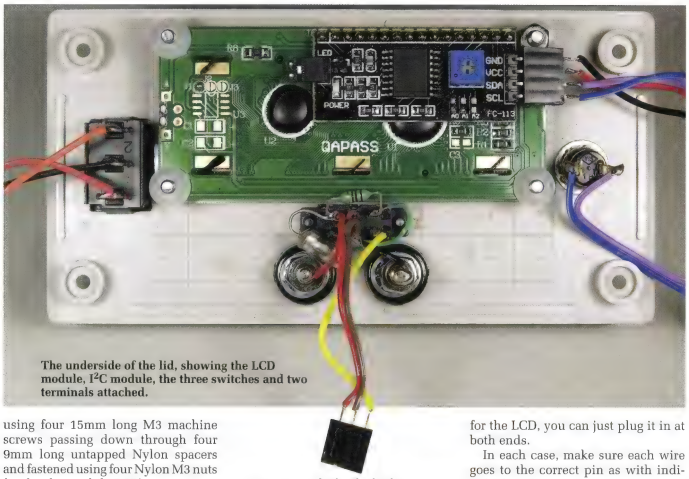
1 LM311 DIP high-speed comparator (IC1; Jaycar ZL3311)
1 1N4148 small signal diode (D1)

Capacitors

2 10µF 16V through-hole tantalum
1 100nF multilayer ceramic
2 1nF 1% NP0 ceramic, mica, MKT, polypropylene or polystyrene (SILICON CHIP online shop Cat SC4273)

Resistors (all 0.25W, 1%, through-hole mounting)

3 100kΩ 1 47kΩ 1 6.8kΩ 1 4.7kΩ



The underside of the lid, showing the LCD module, I²C module, the three switches and two terminals attached.

using four 15mm long M3 machine screws passing down through four 9mm long untapped Nylon spacers and fastened using four Nylon M3 nuts (under the module PCB).

With the LCD module in position, your front panel assembly is ready to be wired up and provided with its various leads to connect to the ProtoShield board.

Refer back to Fig.3 and the internal photo, following them carefully to make the correct connections between S1, the test terminal binding posts and L1 and C1 in particular.

Note that the leads of L1 and C1 should be kept as short as possible, to keep stray capacitance low (and stable). You can then make up the various short leads which will connect the front panel components to the ProtoShield board.

Note that the lead which connects S1, L1, C1 and the test terminals to the ProtoShield ends in a three-way SIL header socket, as does the lead from S3.

In contrast, the lead which connects to the serial LCD module has a four-way SIL header socket at each end, while the lead to connect zero/reset switch S2 (although of only two wires) ends in a four-way SIL header socket, with the wires connecting only to the pins on each end.

The two pins in the centre of the socket can be either cut short or pulled out, since they are not used.

Rather than using SIL sockets like we did on the prototype, we suggest you simply split a 40-way ribbon jumper cable with individual "Du-Pont" sockets on each wire.

This makes the job really easy; you simply pull off the required number of wires and then cut the cable to length and strip the free end, to solder to the switch or connector.

You don't even need to cut the cable for the LCD, you can just plug it in at both ends.

In each case, make sure each wire goes to the correct pin as with individual sockets, it's easy to get them out of order.

Having made up all the required leads, complete the LC Meter assembly with the following steps:

1. Mount the Arduino module inside the bottom of the box using four 9mm M2.5 screws and nuts, using four Nylon M3 nuts as spacers.
2. Plug the LC Meter ProtoShield into the Arduino, making sure you have all four SIL pin headers lined up correctly.
3. Holding the front panel assembly close to the top of the box and orientated correctly, plug the various connection leads into their matching pin headers on the ProtoShield. Be especially careful to get the correct connections between the ProtoShield and the LCD module, as shown in Fig.3.

Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	3	100kΩ	brown black yellow brown	brown black black orange brown
❑	1	47kΩ	yellow purple orange brown	yellow purple black red brown
❑	1	6.8kΩ	blue grey red brown	blue grey black brown brown
❑	1	4.7kΩ	yellow purple red brown	yellow purple black brown brown

Here's the alternative finish using a paper-printed label fixed to the outside of the UB3 Jiffy box lid, after it has been drilled and cut to suit. (You can, of course, glue a paper label to the laser-cut lid purchased from the Silicon Chip online store). In this case the meter is measuring a nominal 100µH inductor and showing it is slightly high at 103µH.

4. Lower the lid assembly down into the box and fix it into place.
5. Program the Arduino, as described below.

Uploading the firmware

In order to do this, you need to have the Arduino IDE installed on your PC.

The latest version of the IDE can always be downloaded from the Arduino website (www.arduino.cc/en/Main/Software).

At the time of writing, the latest version is V1.8.2, dated 22/03/2017. There are various versions available to suit different operating systems: Windows (32-bit or 64-bit), macOS and Linux (32-bit, 64-bit and ARM).

After the IDE has been installed, download our firmware sketch for the LC Meter from the Silicon Chip website (www.siliconchip.com.au). It's called "Arduino_LC_meter_sketch.ino".

Now plug your LC Meter into one of your PC's USB ports, using a suitable USB cable (usually with a Type A plug on one end, and a micro Type B plug on the other). You may need to install the correct USB VCP driver for it if this is not already installed.

If you're using a Freetronics Eleven module, you can download the appropriate driver from their website (www.freetronics.com.au). All of their drivers are zipped up in a file called "FreetronicsUSBDrivers_V2.2.zip", and there's also a document which explains how to install it.

Once the USB driver has been installed and your operating system confirms that it can communicate with the Arduino in your LC Meter, use Control Panel to find out which COM port the Meter's Arduino has been allocated (eg, COM5, COM7, or whatever).

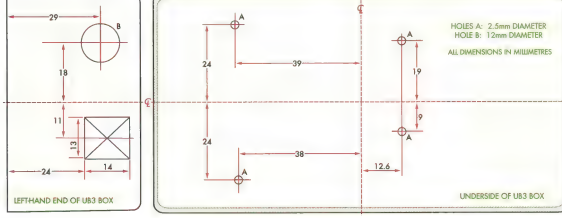


Fig.5: the drilling templates for the four Arduino mounting holes in the bottom of the box along with the USB and DC power access holes in the left-hand end.

Set the port for communication at 115,200 baud with the 8N1 "no handshaking" protocol. The COM port number should be entered into the Arduino IDE's Tools->Port pull-down menu after you start it up.

Now open the LC Meter firmware sketch in the Arduino IDE, verify and compile it, and then upload it into the LC Meter's Arduino flash memory. Soon after it has been uploaded, your meter should spring into life, flashing this message on the LCD screen:

```
Silicon Chip
Digital LC Meter
```

This should remain visible for two seconds, after which the screen should go black, before the Meter begins its initial zero calibration.

If you don't see this initial message, this may be because the contrast trimpot on your LCD display module's serial interface PCB is not set to the correct position.

The remedy is to swing open the lid of the box just enough to fit a very small screwdriver or alignment tool into the trimpot's adjustment slot, turn it and then press switch S2 to force the Arduino to reset and start again.

Try changing the pot setting in one direction or the other until the message becomes clearly visible, pressing S2 after each adjustment.

Startup & calibration

At start-up, the Meter normally expects slider switch S1 to be set in the Capacitance (C) position, and no external capacitor to be connected to the test terminals. If you have done this it will now display the message:

```
S1 set for C: OK
Now calibrating
```

But if you have set S1 in the Inductance (L) position instead, you'll see a different message:

```
Fit shorting bar
Now calibrating
```

This means that the Meter has detected that S1 is set to the L position, and is assuming that you want to do the zero calibration in this mode. As a result, it's advising you to fit a very low inductance shorting bar between the test terminals. This can be in the form of a 40mm long piece of 1.66mm diameter copper or brass rod between the terminals, or (better still) a 40 x 30mm rectangular piece of 1mm thick copper or brass sheet between them. In either case, the rod or sheet must be shiny rather than oxidised.

Note that if you have set S1 to the L position accidentally and don't have a shorting bar available, there's no harm done. Simply flick S1 to the C position and then press switch S2 to get the Meter to reset and begin over again.

Or if you do want to calibrate in inductance mode, simply fit the shorting bar between the terminals (if you haven't already done so) and then press S2 to reset and begin over again.

In either case, there will be a brief pause after which the meter will show the values for C1 and L1 it has found from the initial calibration. This will be something like:

```
C1 = 1084.2 pF
L1 = 91.24 uH
```

The actual values displayed will depend on the components in your unit, as well as the stray capacitance and inductance. They're shown at this stage mainly as reassurance that the Meter is working correctly. The measured values of C1 and L1 will be displayed for three seconds, after which this message will appear:

```
Calibration done
Ready to measure
```

Credit where it's due

As mentioned earlier, this Digital LC Meter, like our earlier May 2008 design, is based on a 1998 design by the late Neil Heckt, of Washington, USA.

Since then, various people have produced modified versions of the design, including Australian radio amateur Phil Rice VK3BHR, of Bendigo in Victoria. Mr Rice and others also modified the firmware and adapted it to use the PIC16F628 micro with its internal comparator. They also added a firmware calibration facility.

So a significant amount of credit for this latest version of the design must go to these earlier designers. The author is happy to acknowledge their earlier work.

This will display for one second, after which the Meter will begin making measurements. If you have done the initial calibration in C mode and S1 is still in this position but no unknown capacitor is as yet connected to the test terminals, you should now get a display like this:

```
Cx = 0.004 pF
(F3 = 515838 Hz)
```

where the value shown for C_x is very close to zero, while the frequency F3 shown on the second line is for the current oscillator frequency; essentially the same as F1 at the current ambient temperature.

The Meter's oscillator frequency does drift a little with temperature. This means that after a while, the value shown for Cx with no external capacitor connected may creep up from the almost-zero reading you get initially. At the same time, the reading for F3 would slowly decrease.

If you find the value shown for Cx

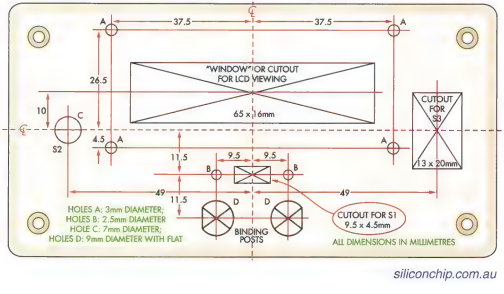


Fig.6: you can either drill and cut the twelve cut-outs required in the lid supplied with the UB3 "Jiffy" box, as shown in this diagram, or (much easier!) purchase a laser-cut acrylic lid from the SILICON CHIP online store and use that instead of the lid that came with the box.

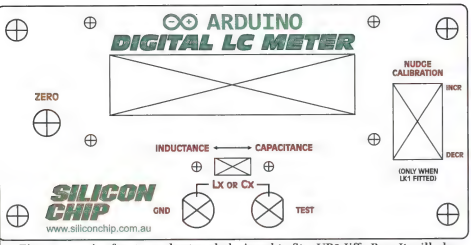


Fig.7: same-size front panel artwork designed to fit a UB3 Jiffy Box. It will also fit the laser-cut acrylic front panel from the SILICON CHIP online store. This, along with the two cutting/drilling diagrams, can also be downloaded (as a PDF) from www.siliconchip.com.au

with no external capacitor has crept up to 0.1pF or more, simply press S2 again to get the Arduino to perform a new zero calibration.

On the other hand, if you've done the initial calibration in L mode and S1 is still in this position but the shorting bar is still connected across the terminals, you should get a display like this:

```
Lx = 0.002 uH
(F3 = 516615 Hz)
```

The value shown for Lx is again very close to zero, and the frequency F3 shows the current oscillator frequency, again very close to F1 at the current ambient temperature. Now if you remove the shorting bar in this mode, you'll find the display will change to something like this:

```
Over Range!
(F3 = 2 Hz)
```

This simply shows that in this mode, an open circuit between the terminals is equivalent to a very high inductance, because it causes the oscillator frequency to drop to near zero.

When you connect a real inductance between the test terminals, the Meter will measure its inductance and display it (assuming its value is within the Meter's range, which is from 10nH to 150mH).

As before, drift in the Meter's oscillator may cause the Lx reading for the shorting bar to creep up gradually. So before making a particularly critical measurement, it's a good idea to fit the shorting bar between the test terminals and press S2 again to force the Arduino to reset and perform a new zero calibration.

Optimising accuracy

If all is well so far, your Digital LC Meter should be operating correctly and ready for use. If you have been able to procure a couple of 1% tolerance (or better) capacitors for C1 and C2, it should also be able to deliver that order of accuracy without any extra calibration.

But as mentioned earlier, it is possible to achieve even better accuracy with the meter providing you have access to a reference capacitor whose value is accurately known (because you've been able to measure it with a high-accuracy LCR meter).

Ideally, this reference capacitor should have a value of between 10nF and 100nF, but even one with a value between 1nF and 10nF would be OK.

This is achieved by tweaking or "nudging" the Meter's reading for the reference capacitor using switch S3. Here's how you do it:

1. Remove the 5V supply from the Meter
2. Lift the lid/front panel up from the box and carefully fit the jumper shunt over the pins for LK1, down on the ProtoShield.
3. Close the box and slide S1 to the C position but don't connect your reference capacitor to the test terminals.
4. Re-apply the 5V power and let the Meter go through its initial zero calibration.
5. Wait a couple of minutes, watching the reading for Cx to see if it drifts up appreciably from the initial near-zero figure. If it does, press switch S2 to force a reset and bring the reading back to less than 0.01pF.
6. Connect your known-value capacitor to the test terminals and note the Meter's measurement reading. It should be fairly close to the capacitor's known value, but may be a little higher or lower.
7. If the reading is too low, press the rocker of switch S3 at the upper ("=") end for a second or so; if it's too high, press the lower end ("-") instead. The reading should change by about 0.5%. Continue until the reading is as close as possible.
8. Remove power, open the lid and remove the jumper from LK1.
9. Re-attach the lid.

Note that since the Arduino always saves the revised calibration factor in its EEPROM after every measurement during this nudging procedure, so you only have to do the calibration once.

Also, when you calibrate the meter in this way using a known value capacitor, it's also calibrated for inductance measurements too. SC

LOOKING FOR A PCB?
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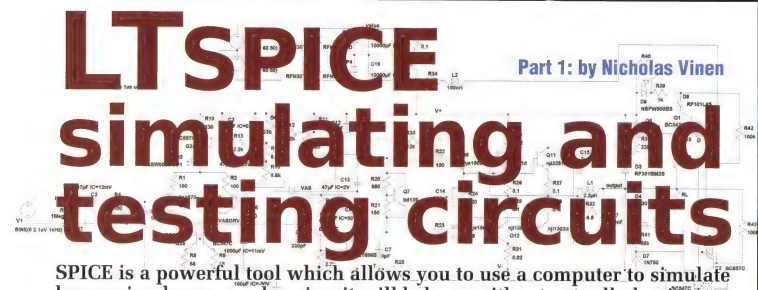
You'll also find some of the hard-to-get components to build your SILICON CHIP project, back issues, software, panels, binders, books, DVDs and much more!
Please note: the SILICON CHIP PartShop does not sell kits; for these, please refer to kit supplier's adverts in this issue.

LTspice simulating and testing circuits

Part 1: by Nicholas Vinen



SPICE is a powerful tool which allows you to use a computer to simulate how a simple or complex circuit will behave without actually having to build it. This allows you to experiment with different configurations and examine the internal operation of a circuit before building it, saving you time and effort.

In this series of articles, we'll take you through installing and using LTspice, a free, easy-to-use and yet very powerful circuit simulation package.

Once you're familiar with LTspice, you can draw up a circuit and start simulating it. Testing circuits in LTspice is a lot cheaper and safer than building them – if you blow up components in LTspice you don't have to buy new ones! Just modify the circuit and try again.

Besides just figuring out whether a given circuit will do what you expect, you can also use SPICE (which stands for **S**imulation **P**rogram with **I**ntegrated **C**ircuit **E**mphasis) to determine certain performance parameters such as stability, efficiency, distortion, noise, reaction time, overshoot, frequency response, power consumption and dissipation, and so on. Throughout this series we'll show you examples of how to calculate all of these parameters.

While SPICE isn't perfect and may sometimes fail to simulate some complex analog circuits reliably, it is quite surprising how close the results of simulations can match the real-world behaviour of a circuit. Note that accurate simulation does rely upon accurate component models and these are not always available.

Simulating a circuit starts with drawing it. During this process you will place component symbols on a sheet and "wire them up".

You will then need to tell the simulator the type code of each component so that it can select an appropriate model. In many cases, for components like resistors, capacitors and inductors, totally realistic behaviour is not terribly important and you can simply use a default "ideal" component.

To get accurate results with devices like transistors and diodes, you would be better off picking one of the available component models which exactly matches the part you intend to use, or at least has similar characteristics. We'll discuss this aspect in more detail later.

Installing LTspice

We're going to use LTspice for Windows in this tutorial series because it's free, easy to install and use and most importantly, is supplied with a fairly large and mostly complete library of component models so that you can get up and running right away.

A component model defines its characteristics. For example, each type of transistor has a different curves for V_{BE}, V_{CE}, h_{fe}, maximum voltage and current and so on. The model provides coefficients so that the simulated component behaves similarly in these respects to an average, real component.

To start off, download the latest version of LTspice from **www.linear.com/designtools/software/** It is available for 32-bit or 64-bit Windows 7, 8 or 10; there is also an older version available for Mac OS X 10.7+. Simply download the executable file, run it and follow the prompts to get it installed. It's a very straightforward process. Once it's installed, run the program and you will see a blank window like that in Fig.1.

Now select the "New Schematic" option from the "File" menu. Not much will appear to have changed

Toolbar Icons

Concentrate your gaze on the right-most section of the toolbar, blown up in Fig.1. From left-to-right, the buttons are:
Wire – connects two or more component pins
Ground – place a ground (0V) symbol on the circuit
Label Net – assign a name to a "net" (more on that later)
Resistor – place a resistor in the circuit
Capacitor – place a capacitor in the circuit
Inductor – place an inductor in the circuit
Diode – place a diode in the circuit
Component – place something else in the circuit, such as a transistor, IC, regulator, voltage or current source, etc
Move – move something around in the circuit diagram
Drag – same as Move, but keeps any wire connections to the selected component(s) intact
Undo/redo – revert the last change to the circuit, or reinstate it
Rotate component – rotates the selected component/components by 90°
Mirror component – flips the selected component horizontally
Text – add text to the circuit diagram
SPICE Directive – add an instruction to the circuit diagram which tells the simulator how to behave

Fig.1: how the LTspice window looks just after creating a blank simulation. The toolbar at top has been blown up to show the important buttons, which are (from left-to-right) Wire, Ground, Label Net, Resistor, Capacitor, Inductor, Diode, Component, Move, Drag, Undo, Redo, Rotate, Mirror, Text and Spice Directive.

but you are now ready to start drawing your circuit. First though, it's best to give it a name. Select "Save As" under the "File" menu, type in "tutorial1" and press Enter.

Chances are that it will say that you don't have permission to save the file into the "C:\Program Files" directory and it will ask if you want to save it in the User folder instead. That's a good idea, so say Yes and then press Enter again to save your file.

We'll now draw up a simple mains power supply circuit. But first, let's look at the toolbar at the top of the window. This is important since you will be using these buttons a lot. The description of each icon in the toolbar is under "Toolbar Icons" at the top right of the next page.

You'll find that you will need to use nearly all these icons when drawing up the circuit you want to simulate. We're going to start by creating a source of 230VAC.

Click on the Component button (which looks like a logic gate). You will then be presented with a list of components and folders (which are in square brackets). Scroll to the right and click on "voltage", then "OK" (or just double-click "voltage").

Click somewhere in the blank circuit to place your first voltage source. This will be simply shown as a circle with positive and negative symbols inside, corresponding to the two output terminals. Note that a voltage source will always take the same form, whether it is intended to produce AC or DC.

Now right click your mouse or press escape, since we only want one voltage source for now.

This is one of the most fundamental parts of a circuit to simulate; the voltage source can generate AC, DC, both AC and DC or a function such as a sinewave or pulse train and is used to feed other components in the circuit. Voltage sources can be combined in various ways.

Voltage source mode setting

There are three different kinds of voltage sources and we need to use the right one to simulate 230VAC mains; refer to the panel titled "Simulation Types" for an explanation.

Having read that, right-click on the V1 element you have placed and then click Advanced. You can now select SINE from the list on the left, and enter 0V for DC offset, 325V for Amplitude (this is the peak value; not RMS), 50Hz for the frequency and leave the rest blank.

Units in these values are optional, however, for clarity it's usually best to include them.

Click OK and the circuit updates to include these parameters. Now click on the Ground button in the toolbar and place a ground symbol directly below the "negative" end of your voltage source.

You need to define 0V somewhere in the circuit if you want to simulate it and this (effectively, the incoming Neutral line), is as good as anywhere. As before, right-click your mouse or press escape to stop placing components.

Now use the Wire tool (leftmost on the section of the toolbar described above) to draw a wire between the negative end of the voltage source and the ground symbol. Click at one end, then the other, then right-

Simulation Types

There are two common types of simulation you can perform, plus several other less common types. The two most common types are "transient" and "AC".

A transient simulation is essentially equivalent to hooking an oscilloscope up to various points in the circuit and then freezing its display to examine how the voltages and currents vary over time. An AC analysis is more like connecting a spectrum analyser with tracking generator up to a circuit.

AC voltage sources in SPICE are primarily useful for AC analysis. For transient analysis, you need a combination of DC voltages or "function"-based voltage sources which are generally one of the following: PULSE, SINE, EXP (exponential), SFFM (single frequency FM) or PWL (piecewise linear).

Basically, if you want an AC voltage source in a transient analysis, you use the SINE function. If you try to use an AC voltage source in this situation, you'll find it won't do anything useful.

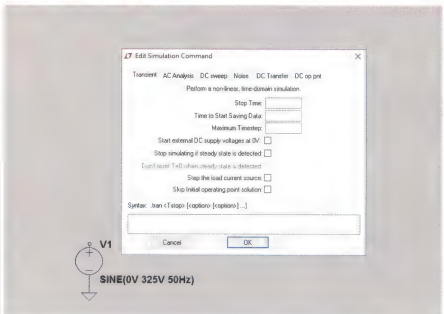


Fig.2: the Edit Simulation Command dialog comes up the first time you select the Run option from the Simulate menu. Select the simulation type from the tabs at the top and then fill in the details below. For a Transient analysis, the most important ones are: Stop Time; Time to Start Saving Data; and Skip Initial operating point solution.

click or press escape to stop drawing wires. Note that if at any point you make a mistake, you can press F9 or click the Undo button on the toolbar to revert to the previous state.

Now we can run the simulation for the first time. Select the "Run" option under the "Simulate" menu. As this is the first time, you will need to set up the simulation conditions, using the dialog which appears (see Fig.2).

"Transient" is the default simulation mode (tab) selected so all you need to do is enter a Stop Time (let's use 100ms) and then click OK. A SPICE Directive automatically appears on the circuit, which reads ".tran 100ms", and you will find a black box appears at the top half of the screen, with the circuit shrinking below.

This is our virtual scope display. Move your mouse cursor down to hover just over the little square box at the positive end of the voltage source in the circuit diagram below and the mouse cursor should change to look like a probe. Click there and you should get a display like Fig.3.

This shows our simulated mains voltage. Of course, the real mains sine-wave is nowhere near as clean as this but it's a good start!

Note the text reading "V(nc_01)" at the top. This indicates that the green trace is showing the voltage at the node labelled "nc_01" which is a name automatically generated for this part of the circuit, as we have not provided our own name yet.

Hold down the CTRL key on your keyboard and click on this label. You will get a dialog box showing information about the "trace" including the start and end times, the average (which is very close to zero, as it should be) and the RMS value which is just under 230VAC; exactly what we wanted. You can now dismiss this dialog.

By the way, if you want to change the parameters later, you can right-click on the ".tran" directive to re-open the simulation dialog.

Building the circuitry

Note that if you already know how to build a circuit in LTspice, you can download the tutorial1.asc file from the Silicon Chip website and skip to the next cross-heading.

If you find yourself confused by the following instructions, refer to Fig.4 to see how the finished circuit looks.

Let's start by adding a capacitor connected to the 230VAC "positive" terminal (effectively mains Active). Click somewhere inside the circuit diagram, then click the Capacitor button in the toolbar and place the capacitor above the voltage source. Right-click the capacitor to set its Capacitance value to 470nF. Set the voltage rating to 400V (peak) at the same time and the RMS Current Rating to 250mA.

Use a similar process to add a resistor to the right of that capacitor and set its value to "10Meg". Note that one of the traps when using SPICE is that "10M" would be interpreted as "10m" (ie, 10 milliohms) so you need to write it with "Meg" on the end. You can set the tolerance to 5% and power rating to 1W at the same time.

Now use the Wire tool to wire the two components up in parallel and connect the common bottom end to the voltage source. Add a second resistor, in series with the capacitor/resistor combination, and set its value to 470 (ohms), tolerance to 5% and power rating to 1W.

The next step is to add two diodes to form a half-wave rectifier. Click

on the Diode tool in the toolbar, then move the mouse down into the circuit. You will notice that if you place it, its cathode will face towards the bottom of the circuit but we want it at the top.

So before placing it, move the mouse back up to the toolbar and click the rotate button twice (note that this button will be disabled before moving the mouse down into the circuit area, so after clicking the diode button, you need to move it down and then back up).

Now place the diode above and to the right of the existing components. Right-click the diode symbol, which is currently configured as a generic (ideal) diode, and click the "Pick New Diode" button. You will now get a list of the diode models built into LTSpice, which includes silicon/switching/Rectifier (standard) diodes, fast recovery diodes, schottky diodes, zener diodes, LEDs and transient voltage suppressors (TVS/varactor).

Scroll down to where the "silicon" type diodes are listed and click on the MURS120 which is roughly equivalent to the 1N4002, then click OK. If the placement of the diode is not ideal, click the "Move" button in the toolbar (or press F7 on the keyboard) and click on D1 to move it to a better spot.

Now we need a second, identical diode so the easiest solution is to clone the one we have. Press F6 on the keyboard, then click on D1 and place the new diode (D2) directly above it. Join the adjacent anode and cathode pins, then connect the free end of the 470Ω resistor to this junction, all using the Wire tool. Connect the free anode at the bottom to ground, as we did with voltage source V1.

Now we need a zener diode. You can clone one of the two existing diodes, placing it immediately to the right of voltage source V1, then right-click on and select "Pick New Diode" to change its type. Scroll down to the zeners and you will find multiple 15V zener diodes in the list (look for 15 in the Vbrkdn(V) column). Pick the KDZ15B as this is a 1W type, then click OK. Move D3 if necessary, to avoid labels from overlapping.

Now connect the zener's anode (bottom end) to ground and the cathode (top end) to the free cathode of the rectifier diode above. Having done that, add a 220µF 25V capacitor in parallel with D3, with a 500mA ripple current rating and ESR of 0.1 (ohms). Also add a 1.5kΩ 10% 5W resistor, simulating a power supply load, in parallel with both. When finished, your circuit should look similar to that shown in Fig.4.

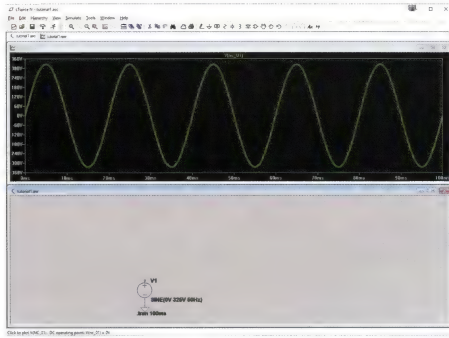


Fig.3: the result of our first Transient simulation, showing the voltage at the top of voltage source V1 over a 100ms period. Note that the 325V figure selected defines the peak voltage, not RMS and that several parameters have been left blank and so default to zero, including the DC offset and phase values.

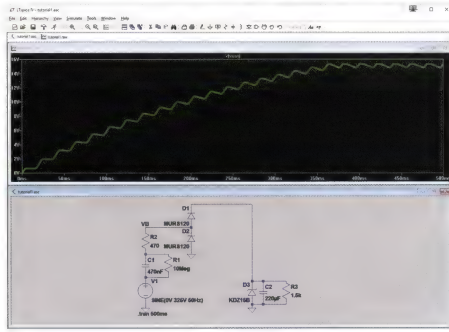


Fig.4: now we've built up a basic mains power supply with a simple resistive load and can observe how the main 220µF filter capacitor charge increases every 20ms during the peak of each mains cycle. We can see that D3 (a 15V zener) begins to conduct after around 350ms, but some ripple remains.

Making some measurements

Right-click on the ".tran 100ms" directive and change the Stop Time to 500ms, then re-run the simulation ("Run" option under the "Simulate" menu). Click on the "wire" at the cathode of D3 to view the resulting voltage. Your result should be the same as shown in Fig.4.

As you can see, it takes around 370ms from the application of mains

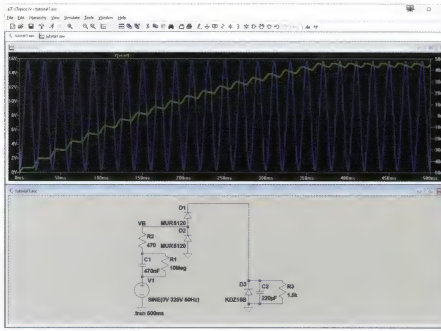


Fig.5: not only can we see the voltage across C2 but now we can also observe the current drawn from the mains as it charges – all without having to wire up a single component and without any test equipment! One of the benefits of using SPICE is how easy it is to make multiple voltage and current measurements.

power before the 220µF capacitor is fully charged to 15V. You can drag a box around the waveform at the top of the screen to zoom in and examine it in more detail (right-click and select "Zoom to Fit" or press CTRL+E to go back to the normal view).

Once zoomed in, you can see that the peak voltage across the capacitor is clamped to around 15.35V and with the 1.5kΩ load, the minimum voltage is around 14.85V, giving a ripple of around 0.5V.

You can make reasonably accurate measurements by placing the mouse cursor over the trace and then reading the time and voltage values shown in the bottom-left corner of the LTspice window. Also, once you've zoomed in, if you CTRL-click the V(n001) text at the top of the screen, it will calculate average and RMS values for the time period displayed, in this case, both around 15.124V.

Now click the mouse in the circuit window at bottom and move the cursor over capacitor C1. You will note that the cursor changes to what looks like a clamp meter. Click here and the current through this capacitor will also be shown in the top window. Note that it is essentially symmetrical and looks like a sinewave with zero-crossing artefacts.

Note also that a new y-axis appears on the right-hand side of the plot, allowing you to see that the peak current through C1 is just below 50mA. You can CTRL-click the label at the top of the display to read off the RMS current which is 33.5mA (see Fig.5).

Efficiency calculations

The efficiency of this circuit is the power delivered to the load (R3) divided by the power drawn from the mains (V1). In both cases, we can compute power as V × I. We could use $V^2 \div R$ for R3 but then we could need to change the calculation if we changed the value of R3, and it would also make it harder to change the circuit to a more realistic load.

To make it easier to calculate both power figures, let's label the two voltages. Click the "Label Net" button in the toolbar and type in "VIN", then press OK. Place the label at the junction of V1, C1 and R1.

Similarly, label the junction of D1, D3, C2 and R3 as "VOUT". Press the DEL key on your keyboard and click on the labels at the top of the simulation output to delete the traces, then re-run the simulation.

Now right-click on the (now blank) top half of the window and select "Add Trace" (or, having clicked in this subwindow, press CTRL-A). It will prompt you for "Expression(s) to add". Type in "V(VIN) * -I(V1)" and click OK. A new trace will appear showing the instantaneous power being drawn from V1. V(VIN) refers to the voltage at the node labelled VIN and I(V1) refers to the current through voltage source V1. "*" is the multiplication operator so giving us the product of the two.

The minus sign before I(V1) just sets the polarity of the result and is something you'd normally need to determine experimentally. You will see that the instantaneous power goes positive and negative at different times in the mains cycle.

This is because sometimes, current flow into C1 is in-phase with the mains voltage and sometimes it is out-of-phase. In other words, there are times when power is flowing from the mains into C1, and times when it is flowing out of C1 and back into the mains.

If you CTRL-click the expression at the top of the window, you will see that the average is 712.21mW and its integral (ie, total energy consumed in the 500ms window) is 356.11mJ.

But note that this includes the time that C2 is charging. So to get an accurate result, right-click on the ".tran 500ms" directive and change the "Time to Start Saving Data" to 400ms, then re-run the simulation. The average is now 783.93mW, which represents a steady-state value, and you will notice that the waveform is consistent across the five mains cycles (100ms) shown.

By the way, if you want to change the expression used to plot the power, you can do this by right-clicking where it's shown at the top of the window.

Now, to compute the power consumed by R3, right-click in the top window (or press CTRL+A) and enter the similar expression "V(VOUT) * I(R3)". If you CTRL+click the new expression which appears at the top of the window, you will see that the average power is 152.69mW (see Fig.6). This is in line with what you'd expect from 15V across a 1.5kΩ resistor ($V^2 \div R = 15 \times 15 \div 1500 = 150mW$).

So we can calculate the efficiency as 152.69mW ÷ 783.93mW = 19.5%. That's pretty lousy! That means that 80.5% of the energy drawn from the mains (630mW or so) is being dissipated elsewhere in the circuit, just turned into useless heat. Luckily, we can use LTspice to figure out where and improve the situation.

First, let's see how much power is

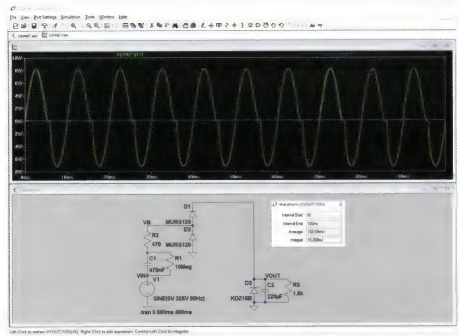


Fig.6: plot of the product of the input voltage and current; LTspice automatically shows the result in watts and changes the Y-axis to suit. The area enclosed by the power curve below the horizontal axis is smaller than that above, with the net power consumption shown in the average (in the box to the right of the circuit).

dissipated in D3, the zener clamp diode. We can simply plot the expression "V(VOUT) * I(D3)" and integrate it as before, to yield a figure of 73.282mW. Well, that's barely more than 10% of the energy being wasted, so that isn't the culprit; we may still be able to make some tweaks to reduce this figure and improve efficiency but let's figure that out later.

What about R2? To calculate the voltage across that, we need to label the wires (nets) at both ends. Let's label the one junction of C1/R1/R2 as "VA" and the junction of R2/D1/D2 as "VB".

We can then plot the expression "(V(VB) – V(VA)) * I(R2)", in other words, the difference between the voltage at points VB and VA (ie, the voltage across R2) times the current through R2.

Integrating this gives us a figure of 529.33mW. Adding this to the power dissipated in D3 gives a result of 602.6mW, explaining over 95% of the power lost in the circuit (the other ~5% is probably in R1). So to improve the efficiency we need to do something about R2.

Improving the efficiency

R2's purpose is to reduce the inrush current into C1 when the circuit is first connected to the mains, especially if that happens to be in the middle of a cycle. If we reduce R2's value, that will reduce its dissipation and improve the overall efficiency but we need to check that this won't cause any problems and also quantify just how much of an improvement we can achieve.

So let's simulate the (almost) worst case, where the circuit is connected to the mains at the peak of 325V and C1 is discharged, and see how low we can make the value of R2 before we risk damaging something.

To do this, rightclick on the body of V1 and enter 90 for "Phi(deg)". We also need to make two changes to the simulation directive, which we can access by right-clicking on the ".tran 400ms 500ms" text.

First, change the "Time to Start Saving Data" back to 0ms so that we can see the initial conditions, then also tick the "Skip Initial operating point solution" box towards the bottom. This tells the simulator to start with all capacitors and inductors fully discharged (although you can specify an initial charge on a case-by-case basis if necessary; we'll explain how to do this in a future instalment).

Re-run the simulation, clear all the traces and plot the current through C1; you can achieve the latter two simply by moving the mouse cursor over C1 until it turns into the clamp symbol and then clicking twice. The first time it will show the current plot for C1 and

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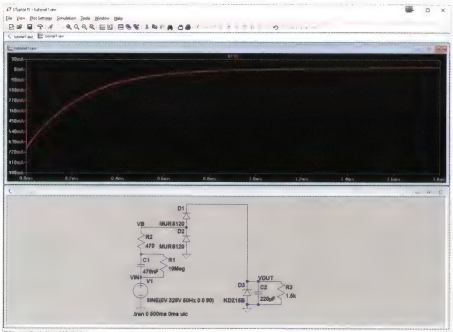

Fig.7: by zooming into the early part of the current trace for C1, we see the inrush current is around 700mA for a fraction of a millisecond. The "uic" on the end of the ".tran" directive is critical; it stands for "use initial conditions" and without it, capacitors and inductors start in a "steady state" condition.

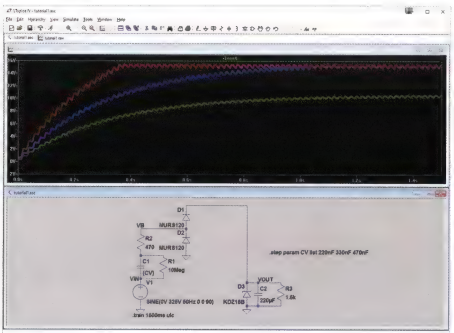

Fig.8: parameter stepping is a valuable method for optimising component values. Here we can see how varying the value of C1 between 220nF and 470nF affects circuit operation. You can also use this method to vary the simulated ambient temperature or to see how component tolerance affects circuit operation.

the second time, it will erase all the other traces except for that plot.

If you zoom into the first few milliseconds you can see that the peak current is around 700mA but this drops very rapidly, to just a few milliamps after 1ms or so (see Fig.7). In retrospect, we could have calculated the 700mA figure simply by assuming that C1 is initially a short circuit and doing the calculation 325V ÷ 470Ω = 0.7A. This suggests that whatever we do to reduce the value of R2 is inevitably going to increase the inrush current but the simulation shows that this is really very brief as C1 rapidly charges up.

Consider that in a real circuit, this would be an X2 capacitor which is designed for direct connection across the mains supply with no real current limiting whatsoever so it should be able to tolerate a high inrush current. So on that basis, let's reduce R2 to 68Ω, giving an inrush current of just under 5A.

The only other components which need to handle this current are R2 (which should be OK given how brief the spike is) and D1/D2 (which will handle much larger spikes as long as they're short or non-repetitive).

At the load end, how much of the initial spike will be borne by D3 and C2 depends on the polarity of the applied mains voltage (ie, whether D1 or D2 conducts) and C2's ESL (equivalent series inductance). Typical ESL of a moderately-sized electrolytic capacitor appears to be pretty low at around 1nH so C2 should safely absorb the brief initial spike, but even if it doesn't, it should not pose much difficulty for D3.

We can now re-run the simulation, adjusting the time to start saving data back to 400ms and calculate the steady-state figures as input power: 327mW, output power: 152.7mW, efficiency: 46.7%. That's a lot better but still not great.

Let's look again at the power consumed in D3, the zener diode. It's virtually identical to before at 73.75mW but now this is around 50% of the power loss. We can reduce this by lowering the value of C1, so that it doesn't deliver more current than the load requires and D3 will then only conduct rarely (eg, if the mains voltage is higher than nominal or the load is lighter than expected).

Parameter stepping

Now we consider whether changing the value of C1 will affect efficiency. It will because if the value is too high, D3 will shunt more of the current coupled through it, effectively wasting power whereas if the value of C1 is too low, the voltage across D3 will not rise to the desired value of ~15V.

What we really want to do to figure out the ideal value is look at the effect of changing the value of C1 with everything else the same. We can do this by stepping its capacitance through different values. To do this, click on the SPICE Directive ("op") button in the toolbar and then type in ".step param CV list 220nF 330nF

470nF". This creates a parameter called "CV" which steps through three different capacitance values.

Now change the value of C1 from 470nF to {CV}. Re-run the simulation, with a start time of 0ms and finish time of 1500ms and plot VOUT. The result is shown in Fig.8.

Unfortunately, LTspice doesn't provide a colour-coding legend but it's fairly obvious that the green curve is for C1=220nF, blue for C1=330nF and red for C1=470nF. 220nF is too low as VOUT doesn't even reach 10V, while with both 330nF and 470nF it reaches the same final voltage, albeit after a different time delay.

So it seems that 330nF is probably close to the ideal value. Let's set the capacitance value of C1 back to 330nF, delete the step directive (press DEL on the keyboard, then click on the directive) and then re-run the efficiency calculations.

Final results

After changing the "Time to Start Saving Data" back to 1400ms and using the same steps as before, we can now compute the input power as 219mW and the power consumed by the load at 151.94mW, only a tiny bit lower than before, giving an efficiency figure of 69.4%. That's pretty reasonable for such a simple circuit, and with a virtually identical load voltage.

So we've barely sacrificed any performance for what is a pretty large improvement in efficiency, all thanks to the ease of simulating such a circuit. Compare this to the difficulty of measuring it, especially when you consider it would be directly connected to the mains!

Apparent power consumption

There are a couple of final issues to discuss regarding simulating this circuit. Firstly, our method of integrating the instantaneous power gives us the real power consumption of this circuit, as would be measured by your power meter (and which would be used to charge you for electricity).

But note that the RMS current drawn from the "mains" (V1) is now 23.65mA with an RMS voltage of 230VAC. That gives an apparent power consumption of 0.02365A x 230VAC = 5.44W.

That tells us that this circuit has a very low power factor. In fact, we can calculate it, it's simply the real input power of 219mW divided by the apparent input power of 5.44W, giving a power factor of 0.04 or 4%. Note that because this is so low, many domestic power meters would have trouble giving any kind of reading at all and the power reading could range from zero all the way up to several watts.

The low power factor is due to the fact that so much of the energy drawn from the mains goes into simply charging up C1 and this is returned later in the cycle, so the power moving into and out of the unit via the mains socket is much higher than the actual net consumption.

Next Month

Modelling relays in SPICE is a little tricky but it can be done, as we will demonstrate by building a fairly realistic relay model next month. We'll also get into some more advanced techniques that are possible with LTspice.

Secondly, there's nothing to stop you from taking the simulation further and actually drawing up a real load instead of using resistor R3. This would give a more realistic depiction of the voltage regulation of this power supply circuit in the face of changing load demands.

For example, this sort of circuit is commonly used to power a relay, either to act as a mains timer or some sort of load-detecting switch.

Actually, if you look at our SoftStarter in the April 2012 issue, Soft Starter for Power Tools in the July 2012 issue and Mains Timer for Fans and Lights project in the August 2012 issue, you will see just this type of circuit.

In those cases, the load current depends heavily on whether the relay is energised and it's acceptable for the supply voltage to drop once the relay has latched, as a lower voltage is required to hold the relay than to switch it initially. So further simulation would definitely help optimise such a circuit. SC

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SERVICEMAN'S LOG

Fixing the food processor that wouldn't

Dave Thompson*

I'm not sure whether it is Sunspots, Murphy's Law or just plain bad luck, but it appears there is a conspiracy among our household appliances to all fail around the same time. Sitting among those appliances that fail is one of our food processors which is only a few years old.

Items Covered This Month

- A Serviceman's kitchen
- Brownout protection for a TV
- TEAC HDR PVR

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Last month it was the vacuum cleaner. Then a fan heater decided to stop fanning and heating. Even my own computer has been increasingly throwing up those cloying "your PC has encountered a problem so we have shut it down" screens.

Between crashes, it often displays weird on-screen artefacts, such as coloured blocks of pixels and very thick black lines appearing randomly. As I write this article, it is as if someone is trying to redact what I am writing in real time. Maybe the CIA really can hack into our homes via our smart fridges (or is it ASIO?)! Hmm, we don't have a smart fridge...

Obviously, the computer has a problem and I suspect my graphics card's VRAM is faulty, though this is a wasted diagnosis because I can't actually do anything about it except replace the card anyway. I'm not about to start stripping memory chips off the thing and replacing them.

Considering that it cost a small fortune and was the single most expensive component in this system, I'm not that happy it has decided to fail just outside of warranty. I would expect more than 16 months out of a high-end graphics card, but that's how it often goes with high-performance hardware.

The irony is that I haven't had time to play the games I originally obtained it for as I am too busy doing far more mundane things, such as renovating workshops, which is proving surprisingly difficult to do whilst actually working out of them.

It's a bit like changing the tyre on your car while driving it down the road; not impossible, as demonstrated by many car-crazy middle-eastern YouTubers, but for the rest of us it is definitely pretty tough.

Now our brand-new dishwasher, purchased when we renovated the kitchen nine months ago, has started making odd noises and during the last few nights, the LED display has been randomly flickering between showing all 8's or nothing, to the time remaining and back again.

I can hurry things up with a light tap on the door, so it looks as if something is not quite making contact somewhere in the electronics behind the door panel.

That'll mean a trip to the repair agent; I have to resist the temptation to go searching for the fault myself. For starters, I haven't the room to pull it to bits in my workshop and besides, Mrs Serviceman wouldn't be too keen on me voiding the warranty!

The curse takes another victim

Now to top it off, one of our food processors has decided it wants to stop processing. This appliance is one of the better and most-used of our kitchen tools so having it give up is a bit of a curse, as it is a few years old now and I'm reasonably sure they don't make them any longer, so we can't just go out and buy another one (which is I'm sure what the manufacturer intended). Then I remembered; I'm a serviceman! This shouldn't be a problem for the likes of me!

This particular mixer has a solid Pyrex glass mixing bowl forming the bottom half of the appliance. A tough plastic lid then clamps securely onto the glass bowl and sitting on that lid is a chrome-and-black plastic housing which contains the motor and drive assembly.

This spins a centrally-mounted twin blade system down through a hole in the lid via a splined drive shaft. This machine is so powerful, you could stuff the bowl full of ice cubes and with a few short bursts of the motor, turn them into slush.

The four curved and razor-sharp blades make small work of anything in the bowl, and while Mrs Serviceman and I aren't great foodies (or cooks for that matter), when the urge takes us, we like to have decent tools with which to do the job.

The problem with this thing was that it no longer powered up. There is no obvious on/off switch; instead, it has an interesting push-switch arrangement. On the very top of the motor housing is a black plastic cap that activates a switch when pushed with the palm of one's hand.

However, for (I assume) safety reasons, there is another switch activated when the whole assembly is pushed against the lid of the bowl. This way, the motor will only run when significant pressure is put on the whole motor assembly and both switches are pushed.

It sounds more awkward than it really is; in use, it is quite natural to push down to start operation. It also makes sense because the motor part of the appliance isn't held down by anything other than the operator's hand pressure.

The splined output shaft of the motor assembly locates into a circular moulding in the thick plastic lid, which is well-fixed to the glass bowl underneath, but other than that hand pressure, the motor assembly is free to move, so it makes sense to hold it tightly when it is running and makes even more sense to require downwards pressure before power is switched to the motor.

Except for the fact that no matter how hard I pushed on it, nothing happened.

So I had to assume that either something was wrong with the switch arrangement or the motor had burned out. I was hoping it wasn't a dead motor, because then we'd likely have to bin the whole thing (although I suppose we could use the bowl for something else). However, this is a classic example of the way everything is going these days. We have become a consumable, throw-away society, and this is very apparent in the kitchen.

Start of Serviceman's rant

By comparison, my mother still uses a mixer she bought in the seventies. Sure, it's had the motor reconditioned a few times and there are a few minor cracked mouldings here and there, but the point is that it was designed to be repaired and there are still parts available for it.

Most of the high-end appliances you buy today don't have anything like the parts backup these older brands have and in 40 years they'll be part of a landfill somewhere while those like Mum's will probably be still going. That's not only hugely wasteful, it's bordering on criminal.

People these days buy new printers rather than buy hyper-expensive cartridges for their old one. Tablet owners chuck a tablet with a broken digitiser rather than repair it, even though in most cases it costs far less than a new one. And people chuck food processors because a part that would cost just a few bucks to manufacture gives out and because the parts aren't there to repair them, and who can blame any of them?

Most manufacturers today are only concerned with moving as many units as they can and don't give a toss what happens to their products once they break down; that becomes someone else's problem.

Increasingly, I cannot source parts for even newer models of computers,

I USED ONE OF MY FAVOURITE TOOLS, AN OLD DENTIST'S PICK

forcing me to look to the second-hand or refurbished market. Most punters these days accept that having to buy a whole new anything is inevitable, the collateral damage of technological progression. And maybe you can't really blame manufacturers for not wanting to have capital tied up in parts sitting around gathering dust on a warehouse shelf somewhere. It's easier to just sell more computers and let someone else create a second-hand or refurbished market.

And that's exactly what has happened; these days many companies are buying up old appliances – whether computers, food processors or washing machines – just to strip them down for spare parts. They know what car wreckers have known for decades; that they can make good money from selling parts rather than selling complete appliances.

This is exactly why I am so keen to get stuck into trying to repair anything that breaks down. I consider it a challenge to buck that wasteful philosophy and try to keep things going for at least a reasonable lifespan. If something wears out to the extent it cannot function any longer, then that's fair enough, but when an entire printer is junked simply because a 20-cent proprietary part is not made available, that is not OK in my book.

Normal service(man) resumes

Getting into this blender motor looked like it could be a challenge. From the outside, there wasn't anything much to suggest how it was held together. There was a hole where the power cable entered the case but that was about it.

After having a closer look at the bottom of the motor assembly, I could see a black plug about 5mm in diameter that could be hiding something. I used one of my favourite tools, an old dentist's pick, to pry the bung out and sure enough, it was covering one of those annoying safety-type screws. I found the right bit for my driver and removed the screw.

After a few attempts to pull the cover off, I concluded that something else must be holding it on. However, I couldn't find anything, and so after sitting and contemplating it for a few minutes, I decided to give it a gentle twist.

Sure enough, the cover slowly gave way to the sideways pressure and after turning ninety degrees, the whole motor mechanism began to pull out from the plastic case. It only came out part way as the power cable held everything in, so I forced the cable through the stress-relieving sleeve bit by bit and pulled the motor far enough out until I could see the power switching arrangement.

The series-wound universal (brushed) motor was switched by a large two-stage microswitch that was actuated by two formed, plastic-capped copper-coloured springs. One of these springs was actuated by pressing down on the plastic cap by way of a captive plastic rod. When the cap was pressed, the rod was forced down onto the spring and that flexed and pressed onto one toggle of the power switch.

The bottom spring actuated the second pole of the switch via a clever little plunger arrangement; when the motor body was pressed down onto the lid of the bowl, a corresponding solid piece of plastic in the lid pressed onto the plunger, forcing it upwards into the second spring and causing that to push the switch's second toggle. Only when the two toggles were actuated would power flow to the motor.

This was actually quite a clever "manual" safety system, as it meant the motor could neither be run without the load of the blades to govern its speed nor without holding it down quite tightly. Pressing down also engaged the blade assembly down in the bowl and unless this was all connected properly, the bottom plastic plunger would not be actuated. Simple and effective; and broken.

The motor wouldn't power on because the bottom spring had somehow broken away from its mount, meaning that it simply flexed out of the way when the plunger touched it, instead of transferring that pressure to the switch.

I hadn't noticed any plastic shrapnel floating around in the case but then again, any fragments might have been small enough to work their way through the small gap for the blade shaft in the lid and fall down into the bowl below. I suppose we'll find them when we defrost and eat the Ćevapi my wife made when she last used the blender!

Now though, I would have to rebuild the support for the bottom spring so I made a rough-and-ready former using strips of gaffer tape stuck to the remainder of the plastic mount. It was originally a rectangular shape and thus easy to recreate. To build it up, I utilised a two-part compound that comes in a tube and one simply slices off a small amount and rolls it to mix it.

It sets rock-hard in about five to 10 minutes, depending on the ambient temperature, so you can't faff about once mixed. Another smaller piece of tape held the contact in place while the pressed-in compound set and I

left it overnight to be certain it was properly cured.

The next afternoon, I removed the tape and tested the contact's travel, making sure it reached and actuated the microswitch. It did, so I reassembled the motor back into the case and with power applied, tried it a few times to ensure it started consistently with the usual amount of pressure. Hopefully, that fix will last and we'll get a bit more use before we have to consider chucking it away.

DIY circular saw upgrade goes awry

And in one of the funnier service moments this month, a customer (and neighbour) brought in one of those bright green, plastic-bodied benchtop table saws that he'd stripped down in order to mount the guts into another more solid benchtop. He'd made a nice job of swapping everything over but had needed to remove the power switch connections and associated wiring in order to get it out of the original housing.

After throwing away all the old parts, he'd fixed the saw and motor assembly into a recessed pocket in a sheet of 32mm custom-wood. That would certainly make a far sturdier base for it than the original flimsy plastic body and thin, cast aluminium table top.

The problem was that he'd chucked away the diagram he'd made of the wiring and was too smart (or afraid) to mess about with mains wiring. Fair enough; sometimes power tools can be wired up in weird ways and just randomly re-connecting spade connectors and plugging it in isn't the best way forward.

The first thing I did was look for a circuit diagram for the saw. I found plenty, all American and not much use for our configuration. I Googled the paddle-style safety switch's part number and found a suitable usage diagram in the datasheet, and with it all wired up correctly, I plugged it into my Variac and wound on 50VAC before pushing the green button. The motor spooled up but there wasn't enough juice to hold the button in. I added another 100 volts and away it went.

Pushing the red "Stop" button switched it off as expected so I called my neighbour to tell him it was ready. The next day, he brought it back, claiming the motor was running backwards. Puzzled, I drew a quick wiring diagram and looked at how changing the connections on the switch would make the motor run in reverse.

There wasn't any configuration that would do that; to swap rotation, I'd have to change either the armature polarity or the field polarity with respect to each other and as it had run properly before, I couldn't see how that was all necessary.

After pondering it for a while, it hit me; he'd put the blade on backwards, which of course made it look as if the motor was running the wrong way. After flipping it, all was well. At least it was an easy fix!

Browned off by brownout protection

G. M., from Pukekohe in New Zealand, recently had a call-out to a remote location to a malfunction in a new TV installation which proved to be a case of "too much protection is too much".

I am the local service agent for a well-known and popular range of home entertainment products. I normally restrict my call-out radius to about twenty-five kilometers from base but this was one of those occasions when Murphy's Law kicked in, and a faulty TV as far away from base as I could be enticed to go became a real head scratcher. This law is closely related to the one which decrees that when a screw is dropped, it will always roll to the darkest, dustiest, most inaccessible corner of the workshop!

A local retailer phoned me with an appeal to talk with one of their customers who had purchased a 55-inch TV three months earlier and he was now convinced the TV was faulty. The farming owner lived near the end of a long peninsula, a 60km one-hour drive over reasonable but quite twisty roads.

I was very busy with other work so I was not keen to waste half a day unproductively driving back and forth all that way, despite the very scenic vistas I would enjoy on the journey. So I was eager to solve the problem by any other means, hoping for an installation or operation issue which I could talk the owner through.

I phoned the owner and he explained his problem. The TV would completely cut out for two to three minutes and then come on again with no sound or picture. It would repeat this several times an evening and it was happening virtually every night. Soon after cutting out, the screen would show the word "SAT" in the top left corner. When the picture and sound eventually came back on everything worked normally until the next time. He had only experienced these problems since purchasing the new TV. The old plasma TV had worked just fine.

I asked some obvious questions such as whether the problem was occurring on all sources which was responded to with a considerable pause. So I clarified my question by asking if there was anything else connected to the TV such as a set-top box or DVD player. Yes, there was a Sky box (pause again); not sure about a DVD player. Now we're getting somewhere – or are we? I gained the impression that he was not sure what a DVD player was. He only watched Sky broadcasts.

The owner explained that he had had the Sky people out twice attempting to solve the issue and they had eventually replaced the decoder, to no avail. Having eliminated that as a cause, he surmised that the problem now had to be with the TV. He even took a photo of the malfunctioning TV

with his phone and sent it to me so he was obviously not completely technophobic! I talked the owner through the procedure to reset the TV to factory condition and left him to test it that night.

The next morning, I phoned a couple of satellite installers whom I knew and discussed the possibility of there still being a decoder or satellite signal issue since this was not my area of expertise, but neither of them were convinced that the problems were Sky related. However, since they had both been in the trade nearly as long as me, neither was prepared to lay odds that it was not a Sky reception fault.

Meanwhile, I forwarded the photo to the TV brand's technical manager and had several discussions with him by email and phone regarding the fault. He seemed to be quite certain that the "SAT" logo appearing on the screen was not something being generated by the TV so the problem had to be elsewhere. We were running out of elsewheres.

The last straw caused the frustrated owner to send a curt text to my phone a couple of days later that 'Now everything had cut out, nothing was working – I'll pay for you to call'. I phoned him and waited while he fetched an electric drill to plug into the wall to test that the power was on. The drill whirred into life so I said I'd think on it and let him know. He was slowly convincing me that the TV was to blame and had somehow now caused everything to fail.

I talked with the brand's head technician again and he agreed to cover the considerable cost of a call out if it proved to be a TV fault. I phoned the owner and he was happy for me to call on the basis that if it was not the TV at fault then he had to bear the cost. He was quite convinced that the TV was faulty, so was confident that he would not be writing a cheque.

I called the next day armed with a small loan TV of the same brand with a twofold job for it – first, to pacify the owner by leaving him something to watch and second, to act as a test unit while I checked his new TV at my shop.

The first thing I noticed when I arrived at his home was that there was indeed no power. The TV, decoder and sound bar/sub-woofer were all dead. Up until this point I had not known there was a sound bar. It was now I also learned that the TV and sound bar had been delivered and installed by the retailer at the time of purchase.

I knew there was power to the wall so I peered over the back of the TV and saw a nice new multi-outlet power box there, no doubt sold by the retailer as an add-on to give protection to the new equipment in the event of a power surge. In my opinion this is a duplication of the sort of protection which is now already built into most equipment, but having been a retailer myself in a past life, I was not about to cast aspersions on the practice of up-selling.

The box had an on/off switch on the top so I reached for it and toggled it to the other position at which point I was greeted by an encouraging green glow from beneath the switch button and now everything was working.

I quizzed the elderly couple about how the switch could have been bumped off since there were obviously no children around at which point the lady admitted that one of her cats had chased a mouse behind the TV the previous day and must have jumped on the switch. This seemed quite plausible since the switch button was quite large and the switch took little effort to operate.

So, the immediate no-power problem was solved but I was fairly sure this had no connection (pun intended) with the original complaint so I carried on with swapping the TVs and after the loan TV was connected and working, I checked some of the menu settings on the decoder and sound bar. These were both connected with HDMI cables to the TV.

I've experienced some odd behaviour in the past by allowing such appliances to talk to each other. I went into the menu of each device and switched off this interactive feature to eliminate arguments between them as a possible cause of the original complaint. If the owner wants this feature, it can be readily restored, once our present issues were behind us.

Back at base I connected the new TV to an HDMI source and left it running. It didn't miss a beat. That evening I received a text from the exasperated owner to say the same thing was happening with the loan TV except that this TV displayed the "HDMI1" in the top left corner, not "SAT" which the new TV had displayed.

It was now that he offered a little more information which in hindsight, I probably should have asked about earlier. The problem only seemed to occur at around dinner time each evening and it did not happen so often later in the evening.

Now armed with another clue in the timing of the fault occurring, I wondered whether this could be a power supply problem after all, but the owner wasn't convinced of this since despite living at the end of the road at the tip of a long peninsula, it couldn't be a power voltage drop because the lights remained bright.

Now clutching for straws and wanting to resolve the problem before I headed away for a brief break in a few days, I connected the new TV in my shop to a variable transformer just to eliminate that from the mix of possibilities. I slowly reduced the voltage from the normal 230VAC and I was surprised that the TV worked perfectly down to 80VAC, at which point it cut out. As soon as the voltage came up a bit, the set burst back to life without so much as a hiccup. I reset the TV a second time and adjusted some of the menu settings.

The next day was a public holiday. Despite that and being so keen to get on top of the problem, I loaded the owner's TV into the van. I included the variable transformer and set off with some trepidation, knowing that if I did not solve the problem this time

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around, I would have to admit defeat. Who would want to pay me for the many hours I had already invested in this job if I couldn't provide a solution?

On arrival, I connected the variable transformer to the wall socket and the multi-outlet box in turn to the transformer and turned everything on. As I slowly reduced the voltage from 230VAC to just above 200VAC there was a click and everything died. Turning the voltage back up a little produced another click and everything except the sound bar powered up again.

The clicking noise was coming from the power multi-box and it was now obvious to me that this was a feature of the device to protect connected appliances against brown-out damage due to prolonged low voltage supply. A press of the power button on the sound bar remote control turned that on again.

When I repeated the exercise, I noticed the TV came back on almost immediately after the voltage was restored but the Sky decoder took several minutes to reboot itself. In the meantime, the TV patiently displayed a blank screen with "HDMI1" showing in the top left corner, until it once again received a signal from the decoder and then displayed a perfectly normal picture.

These were exactly the symptoms the owner had described. Eureka! After substituting the power multi-box with a cheap discount store version, without the brown-out protection feature, he has had no further problems – so far.

Epilogue

So I had been hoodwinked by a technological feature of the power outlet multi-box which I did not realise it had. In any other location, the protection would most likely not have tripped until a real and rare brown-out event happened and I would have remained blissfully unaware of the feature.

After the power was restored and the protection reset, the viewer would continue to enjoy uninterrupted television for many more months or even years, before such an event might happen again to trip the protection.

Since I was never present in the owner's home when the unprompted fault happened, I can only suspect his mains voltage is regularly dropping below 200VAC. I was not planning to spend an evening there monitoring the mains voltage to find out. I suggested to him that he purchase a $30 plug-in power monitor available from Jaycar to check for himself; it is not uncommon for there to be power fluctuations in rural locations.

The owner was hoodwinked into believing he did not have a power problem by a different technology – CFL lights which maintain their brightness despite the voltage drop. Unlike incandescent lamps which give a visual indicator of the voltage of your power supply; flickering or obviously dimming when the voltage dropped.

Yet another hidden and overlooked clue was that the Sky decoder was housed in a cabinet with a tinted glass door, so it was not obvious to the owner that the decoder was going through its reboot sequence after the power interruption. All he saw was the blank TV screen which came back to normal by itself after a few minutes.

I suggested the owner have an electrician check his power supply as such a severe voltage drop could suggest a high resistance in one of the three phases supplied to the property, which in turn could pose a fire risk. All of this happened in late summer so it was destined to be much more of an issue come mid-winter when heaters, hot water and ovens are all working harder.

The "SAT" word which sidetracked me briefly must have been programmed into the new TV when it was installed by the retailer. I was surprised he had gone to this much trouble. It is a feature within the menu of some TVs which allows you to enter your preferred label for the various inputs. Resetting the TV the first time erased this entry and it defaulted back to the HDMI1 label.

Another little twist was that despite purchasing a nice sound bar and subwoofer, again maybe an upsell by a keen salesman, the new owner was missing out completely on the much-improved sound these systems offer over the standard TV speakers.

From the very first time the power dropout happened, the speaker system had not automatically restarted. It was the only device not to do so and despite a scan through its menu, I could not find any reference to power settings which would allow me to select auto power on. It probably relies on the HDMI interaction feature which I mentioned earlier, switching itself on or off in sync with the TV.

The owner had been using the TV speakers only and I know this because he complained that he had to hold the TV remote control high in the air

to adjust the volume. The sound bar was blocking the infrared signal to the TV, unless the remote was raised sufficiently above it.

When I explained to the owner that he needed to deliberately power the sound bar back on after a power interruption, I could tell he had not been doing so. In fact, he was completely unaware that it had not been working and that he had been missing out on much improved sound fidelity from his entertainment system.

I had another job recently with a near new TV which came in for service with both speakers blown; this despite the owner having a sound bar. I wonder if this was another case of the sound bar not being able to come back on automatically after a power interruption?

Faulty capacitors don't need to be bulging

L. W., of Logan, Qld, replaced bulging capacitors on the main board of his malfunctioning PVR and thought that would fix it. But it wasn't that simple and it took a lot more detective work to complete the repair.

About 12 months ago, my TEAC HDR 1600T Personal Video Recorder began to exhibit erratic operation until it finally failed and would not complete its start up boot process, hanging approximately half-way through.

I had experienced problems before with the unit which had turned out to be a bulging electro in the power supply circuit, so it was with some hope that I removed the cover to take a look inside.

After spending some time examining the power supply and finding no signs of distress, I turned my attention to the main board. Only part of this board was visible as the hard drive is mounted above it. There was nothing obvious here either so I decided to switch on and measure the outputs from the power supply.

I waited for it to complete as much of the boot process as it could and then took some measurements. There was no joy here as all appeared to be well within tolerance. At this point I started to lose interest as the machine was now getting a little long in the tooth and much better machines with larger hard drives are available on the market.

However, there were a couple of weekly shows that I had recorded and I really did want to view them. I decided to remove the hard drive for a better look of the main board. And it was here that I struck pay dirt or so I thought. Under where the hard drive had been sitting I could clearly see three electrolytic capacitors with their tops bulging.

I didn't have any of the correct values (all three were 220µF 16V types) so after a quick visit to the local electronics store, I wasted no time fitting the capacitors and replacing the main board. The HDD was reinstalled, power supply connected and switched on.

Well, you can imagine how I felt when this time there was even less response from the unit than before I had started. In disgust, I switched off, pushed it to the rear of the bench and that's where it sat for 12 months.

During that time it got in my way on several occasions but I just ignored it as best I could. I did make an attempt to boot the HDD from my PC in an effort to retrieve the information from it but even with the assistance of the internet I wasn't able to achieve an end result.

Having recently purchased a replacement machine, the time came to decide whether to have another go at fixing it or consign it to the wheelie bin. It was still in a dismantled state and picking up the main board, I noticed that there were several other similar capacitors in the same area as the ones I had previously changed.

All were black with blue labelling while most of the other electros on the board were black with white labelling. So for no other reason I decided to change those too, as I felt the symptoms dictated a faulty electro somewhere.

I didn't have the correct values but decided to use what I had at hand rather than waste any more money buying new ones. In all I ended up changing CE2, 3, 11, 15, 16, 24, 29 and CE223.

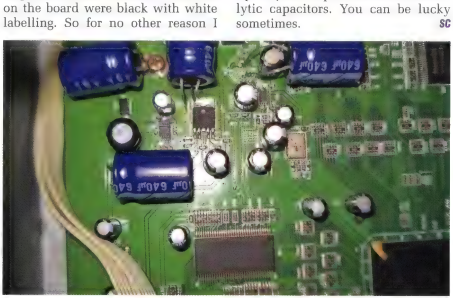
Some of the capacitors I used were physically bigger, so I had to leave their legs fairly long and bend them over into what space I could find so as to reinstall the HDD which, as stated, fitted over the whole lot. The photo shows some of the replacement capacitors.

I didn't hold much hope of success, so it was a surprise when the machine booted up and all appeared well. That was several months ago now and I am gradually catching up on episodes of the weekly shows I had recorded some 12 months ago.

However, it did bug me in not knowing which capacitor was actually the culprit. So one night I fired up the scope and oscillator and measured the ESR of the capacitors that I had replaced the second time around.

Again to my surprise, while it was a 220µF capacitor like the bulging ones I had originally replaced that was obviously faulty, all the others were at various stages of deterioration, with much higher ESR than they should have exhibited.

So there you go; another piece of electronic equipment saved from the tip for just the price of a few electrolytic capacitors. You can be lucky sometimes. **SC**



Bulging 220µF 16V electrolytics weren't the only issue in this video recorder as it wasn't until some of the larger capacitors were changed due to high ESR values that the set came back to life. This photo shows the new capacitors installed.

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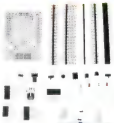

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USB LEAD WITH VOLTAGE & CURRENT DISPLAY

Displays the voltage and current alternately to its easy to read LCD display.

- USB A to USB Micro B

XC-5072 **WAS $19.95**

NOW $9.95
SAVE 50%

Phone not included.

HALF PRICE

ARDUINO® PROJECT OF THE MONTH

USB-SERIAL CONVERTER

This project is great if you've decided you want to go beyond what the pre-built Arduino boards can offer. Whether you're looking to reduce power consumption, make your project smaller or even just learn about microcontrollers at a deeper level, then building this will help you. Along the way, you'll learn about ways to use a USB-Serial converter for Arduino sketch upload and communication.

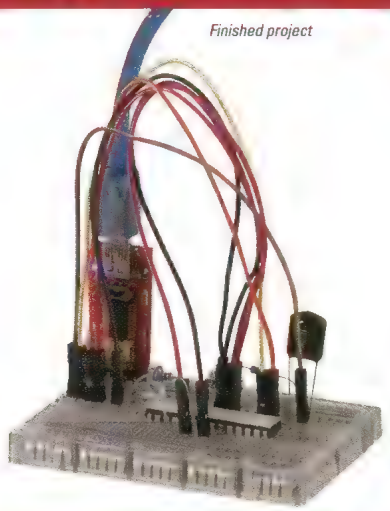
KIT VALUED AT $48.50

NERD PERKS CLUB OFFER
BUY ALL FOR
$34.95
SAVE OVER 25%

DIY

MORE INFO ONLINE

Finished project



WHAT YOU WILL NEED:

ATMEGA328P IC AND 16MHZ CRYSTAL
ZZ-8727 **$12.95**

USB- SERIAL CONVERTER XC-4464 **$19.95**

PLUG-PLUG JUMPER LEADS
WC-6024 **$5.95**

BREADBOARD
PB-8820 **$7.95**

10KOHM RESISTOR PACK
RR-0596 **$0.55**

100NF POLYESTER CAPACITOR
RG-5125 **30¢**

RED LED
ZD-0152 **85¢**

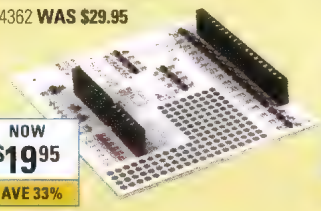
SEE STEP-BY-STEP INSTRUCTIONS AT
www.jaycar.com.au/usb-serial-converter

SEE OTHER PROJECTS AT
www.jaycar.com.au/arduino

VOLTAGE CONVERTER MODULE

Safely marries 5V Arduino® shields with the 3.3V pcDuino to stop damage caused by connecting a 5V shield to pcDuino.
- 70(L) x 50(W) x 4(D)mm

XC-4362 **WAS $29.95**

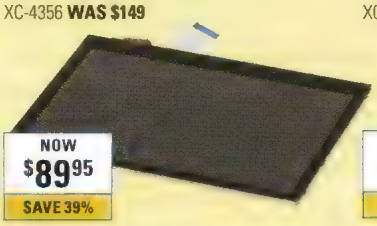


NOW $19.95
SAVE 33%

7" LCD TOUCH SCREEN MONITOR

- 1024 x 600 resolution
- LVDS screen with driver board
- 167(L) x 107(W) x 10(D)mm

XC-4356 **WAS $149**

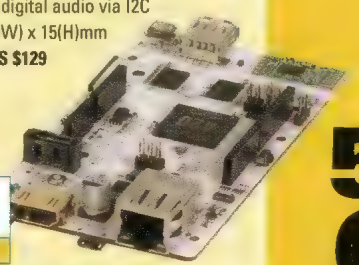


NOW $89.95
SAVE 39%

PCDUINO V3.0 WITH WI-FI

- Built in Wi-Fi capability
- Supported digital audio via I2C
- 121(L) x 65(W) x 15(H)mm

XC-4350 **WAS $129**



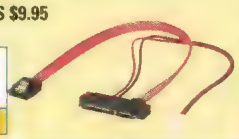
NOW $89.95
SAVE 30%

UP TO 55% OFF PCDUINO & ACCESSORIES

SATA CABLE

Connects your pcDuino V3.0 to a hard drive or SSD.
- 150mm long (approx.)

XC-4366 **WAS $9.95**

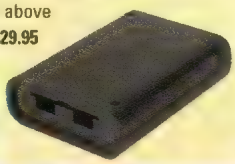


NOW $4.95
SAVE 50%

BLACK ENCLOSURE

House your pcDuino in this enclosure for a safe and presentable appearance.
- Suits XC-4350 above

XC-4354 **WAS $29.95**



NOW $19.95
SAVE 33%

PCDUINO 5MP CAMERA

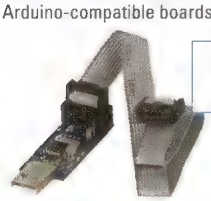
Connects directly to pcDuino V3.0, and captures an active array of video and images up to 2592 x 1944 resolution.

XC-4364 **WAS $44.95**

NOW $19.95
SAVE 55%

ISP PROGRAMMER FOR AVR

Unbrick, install or update Arduino-compatible boards. XC-4627



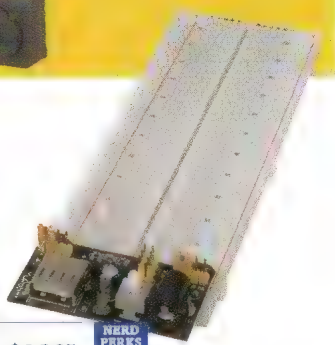
$14.95 NERD PERKS 2x POINTS

JUMPER LEAD ASSORTMENT KIT - 90 PIECES

Use in Arduino® projects, school experiments and other hobbyist activities. 220mm long.
WC-6029 **ORRP $14.95**

NOW $8.95
SAVE 40%

$9.95 NERD PERKS 2x POINTS



$19.95 NERD PERKS 2x POINTS

ELECTRONIC CIRCUIT BOARD CLEANER

Non CFC ozone safe propellant. Dissolves flux residues & grime leaving the track work and board clean. NA-1008

ALSO AVAILABLE:
CIRCUIT BOARD LACQUER
NA-1002 **$11.50**

$11.50 NERD PERKS 2x POINTS

PCB ETCHING KIT

Complete with assortment of double-sided copper boards, etchant, working bath and tweezers. HG-9990

$27.95 NERD PERKS 2x POINTS

BREADBOARD POWER MODULE

Adds a compact power supply to your breadboard.
- Plugs straight into most breadboards
- Can be set to 3.3V or 5V
- Concave design saves space

XC-4606

SOLDERLESS BREADBOARD WITH POWER SUPPLY

830 tie-point breadboard with removable power supply module. Includes 64 mixed jumper wires of different length and colour.
- 3V and 5V switchable output

PB-8819

WORKBENCH ESSENTIALS

There has been an obvious resurgence in people getting back to the workbench and reviving skills involving manual dexterity. As you will see across the following pages, Jaycar has all the DIY tools you'll need to equip your workbench so you can create projects from the power of your brain and your hands.

1. BENCHTOP WORK MAT HM-8100 **WAS $12.95**
- Durable A3 size PVC cutting mat is just the thing to protect your work benchtop
- Ruled with a centimetre spaced grid for easy referencing
- 3mm thick- 450 x 300mm

2. 115 PIECE PRO SOLDERING GAS KIT
TS-1115 **WAS $129**
- Ideal for the handyman, electrician or hobbyist
- Pro Gas Soldering Iron with spare tips and accessories
- Supplied in a hard plastic carry-case
- 130(W) x 150(D) x 70(H)mm

See website for full contents.

3. VACUUM BENCH VICE WITH 75MM JAW
TH-1766 **WAS $39.95**
- Made from hard-wearing diecast aluminium
- Vacuum base and ball joint clamp
- 75mm opening jaw
- 160mm tall (approx)

4. LONG BIT SCREWDRIVER SET
TD-2114 **WAS $34.95**
- Includes popular slotted, Phillips, Star and TRI bits.
- 22 pieces

5. 60W ESD SAFE LEAD-FREE SOLDERING STATION
TS-1390 **ORRP $159**
- Easy temperature setting, Fahrenheit or Celsius temperature display
- Backlit LCD display
- Temperature range: 160°C to 480°C
- 130(W) x 170(H) x 240(D)mm

6. MAGNIFYING LAMP WITH THIRD HAND
TH-1989 **WAS $44.95**
- LED illuminated 3x magnifying glass
- Soldering iron stand, alligator clips, solder spool holder, cleaning sponge & ball
- 4 x AA batteries required
- 190 x 170mm base size

NOW $29.95 SAVE $5
NOW $99 SAVE $60
NOW $99 SAVE $30
NOW $24.95 SAVE $15
NOW $39.95 SAVE $5
NOW $6.95 SAVE $6

HALF PRICE

16W BATTERY OPERATED SOLDERING IRON

Designed to be powered off any 7.2V rechargeable battery (Ni-Cd, Ni-MH, Li-ion, Li-Po) commonly used in electric remote controlled cars.
- Compatible connector (use PP-2020 $2.75 sold separately)
- 1.5m lead
- 205mm long

TS-1538 **WAS $14.95**

NOW $7.45 SAVE $7.50

PORTASOL® GAS SOLDERING IRON

Combines compact power, and convenient reliability, making it one of the most versatile gas soldering irons available.
- Adjustable temperature up to 450°C
- Built-in flint type ignitor in end cap
- Operating Time: 60 min (approx.)
- 170mm long

TS-1305 **WAS $59.95**

NOW $49.95 SAVE $10

14 LED ADJUSTABLE COLOUR LAMP WITH LCD CLOCK

Displays the date, time and temperature. Adjustable head and arm provides perfect lighting angle.
- 3 light modes: warm white, cold white and natural
- Foldable structure
- Zero UV light output
- Touch sensitive switches
- 330(H) x 145(L) x 145(W)mm

SL-3142 **WAS $69.95**

NOW $29.95 SAVE $40

OVER HALF PRICE!

$39.95

HEATSHRINK PACK WITH GAS POWERED HEAT BLOWER

An assortment of 160 heatshrink tubes in 7 different colours and sizes, plus 1 gas powered heat gun with Piezo ignition and flame or flameless output.
- 242(L) x 175(W) x 30(H)mm

TH-1620

FREE BUTANE GAS*
*Valid with purchase of TH-1620. Company owned stores only.
NA-1020 VALUED AT $4.95

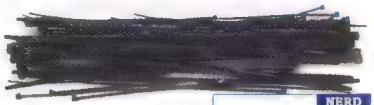
15A POWER CABLES - 10M ROLL

Flexible DC power cable suitable for general purpose automotive and marine applications. 15A rated current. Total diameter is 3.3mm.

RED WH-3054
BLACK WH-3055
GREEN WH-3056

$11.95 ea NERD PERKS 2x POINTS

$12.95 NERD PERKS 2x POINTS



EXTRA LONG MIXED BLACK CABLE TIE SET

Contains 70 black cable ties of various lengths up to 500mm.

HP-1209

$18.95 NERD PERKS 2x POINTS

PRECISION ANGLED SIDE CUTTERS

Made from quality tool steel with soft padded handles, spring loaded for comfortable long term use. 127mm long.

TH-1897

10% OFF
ALL DIGITAL MULTIMETERS

NOW $8.95
SAVE 10%

CATII 500V
Ideal first multimeter with plug-in 4mm probes and transistor tester.
- 2000 count
- Volts DC/AC: 1000V/750V
- AC/DC Current: 10A
- 125(L) x 68(W) x 23(D)mm

QM-1500 **WAS $9.95**

NOW $62.95
SAVE 10%

CATIII 600V
Non-contact voltage, duty cycle, relative measurement. Fold-out stand. Autoranging.
- 4000 count
- Volts DC/AC: 600V/600V
- AC/DC Current: 10A
- 138(L) x 68(W) x 37(D)mm

QM-1551 **WAS $69.95**

NOW $84.95
SAVE 10%

CATIV 600V
IP67 rated. Duty cycle, relative measurement. Autoranging.
- 4000 count
- Volts DC/AC: 1000V/1000V
- AC/DC Current: 10A
- 182(L) x 82(W) x 55(D)mm

QM-1549 **WAS $94.95**

NOW $39.95
SAVE $10

RECHARGEABLE SCREWDRIVER KIT
Powerful high torque electric driver, stainless steel bits and aluminium carry case.
- 250(L) x 153(H) x 88(D)mm

TD-2491 **WAS $49.95**

NOW $69.95
SAVE $30

PLASTIC WELDING KIT
Repair small/medium cracks and deep scratches on bumpers, bodywork panels, headlights and engine parts.
- Fast heating process
- 4 plastic filler types included

TS-1331 **WAS $99.95**

PRO HIGH TEMPERATURE NON-CONTACT THERMOMETER
Measure high temperatures with safety.
- Laser pointing targeting
- Temp range: -50 to 1000°C
- 30:1 distance-to-target ratio
- Backlit LCD
- 230(L) x 100(H) x 56(W)mm

QM-7226 **WAS $249**

NOW $199
SAVE $50

SAVE $50

1MHZ FUNCTION GENERATOR
Produces accurate sine, square & triangle waveforms with adjustable frequency & amplitude.
- 8Vpp max output voltage
- Linear or logarithmic, single or bidirectional
- 114(h) x 74(W) x 29(D)mm

QT-2304 **WAS $299**

Company owned stores only. Not available online.

NOW $249
SAVE $50

SAVE $50

PROFESSIONAL DIGITAL LIGHT METER
Uses photopic spectral sensitivity which closely mimics the response of the human eye to changes in light. Measurement can be switched between LUX and FC (foot candles).
- Long-life silicon photo diode sensor
- Min & Max measurements
- Easy to read backlit display
- Data hold

QM-1584 **WAS $169**

NOW $134
SAVE $35

SAVE $35

PROFESSIONAL LASER DISTANCE METER
Highly accurate. Easily measures the distance between two points (beyond the capabilities of the common tape measure). Automatically calculate area, volume or height.
- Measurement 0.05 to 35m (±1.5mm)
- Stores up to 20 measurements
- 100(L) x 45(W) x 27(H)mm

QM-1622 **WAS $179**

Company owned stores only. Not available online.

NOW $149
SAVE $30

SAVE $30

NOW $149
SAVE $30

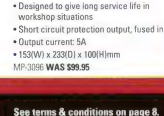
0 TO 30VDC 5A REGULATED LAB POWER SUPPLY
- Digital control, large LED display
- Built-in over-current & short circuit protection
- Output current: 0-5A
- 110(W) x 156(H) x 260(L)mm

MP-3840 **WAS $179**

NOW $119
SAVE $30

0 TO 24V 17A COMPACT LAB POWER SUPPLY
- Compact size, high current & variable output
- Output voltage: 0-24VDC
- Output current: 17A max
- 148(W) x 162(D) x 82(H)mm

MP-3800 **WAS $149**



NOW $79.95
SAVE $20

13.8V 5A FIXED LAB POWER SUPPLY
- Designed to give long service life in workshop situations
- Short circuit protection output, fused input
- Output current: 5A
- 153(W) x 233(D) x 100(H)mm

MP-3096 **WAS $99.95**

SAVE UP TO $30 ON THESE LAB POWER SUPPLIES

SAVE $100

HDMI DISPLAY RECEIVER

Turn your HDTV into a Smart TV! Stream videos, music and photos wirelessly from your computer or DLNA enabled Android Smartphone or Tablet to your TV. Connects via HDMI (sold separately).

- Doubles as a Wi-Fi router
- Supplied with software and power adaptor
- 130(L) x 64(D) x 20(H)mm

AR-1914 **WAS $149**

NOW $49

SAVE $100

HALF PRICE

N600 DUAL-BAND WI-FI ENTERTAINMENT BRIDGE

The ideal solution to upgrade your out-dated 54Mbps 11b/g devices to super-fast 300Mbps wireless connection. Dual-band option (2.4 or 5 GHz) to avoid interference with other devices. Extremely easy setup through Wi-Fi or built-in Wi-Fi Protected Setup (WPS) button.

- Supports two simultaneous devices
- 100(D) x 95(Dia)mm

YN-8368 **WAS $59.95**

NOW $29.95

SAVE $30

70% OFF

6-WAY SWITCH PANEL WITH RELAY BOX

Ultra compact 12VDC touch control panel to control devices in automotive, camping, or marine applications.

- IP67 rating

SP-9900 **ORRP $99.95**

NOW $29.95

SAVE 70%

30% OFF

UHF WIRELESS GUITAR TRANSMITTER AND RECEIVER

Complies with the latest UHF frequency allocations. Operates on either 520.5MHz or 532.9MHz user selectable.

- 60m max range
- Adaptor supplied
- Output via 3.5mm socket

AM-4109 **WAS $99.95**

NOW $69.95

SAVE $30

OVER 40% OFF

COMMUNICATION SPEAKER

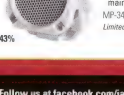
Small but powerful unit delivers clear voice from either VHF, 27MHz or even HF communications receivers. Waterproof. Mylar speaker cone.

- 2.25WRMS @ 4Ω
- 1.5m cable terminated to a 3.5 plug

AS-3186 **ORRP $24.95**

ALSO AVAILABLE:

10WRMS @ 8Ω AS-3187 **ORRP $29.95 NOW $16.95 SAVE 43%**



NOW $13.95

SAVE44%

4 PORT USB MAINS TRAVEL ADAPTOR

Allows you to recharge 2 iPads and 2 smart phones at the full rate at the same time!

- 5A total current
- Four interchangeable mains fittings

MP-3441 **WAS $34.95**

Limited stock.

NOW $19.95

SAVE 42%

NOW $23.95

SAVE 46%

12VDC 13.5A UNIVERSAL RELAY WIRING KIT

Universal relay wiring kit for fitting various 12V devices to your car, such as our LED driving lights.

SY-4180 **ORRP $44.95**

SAVE UP TO 40%

ON THESE IT PRODUCTS

HIGH DEFINITION 720P WEBCAM WITH MICROPHONE

Features a five-layer lens, high-resolution CMOS colour sensor ideal for video conferencing or webcam chat.

- 5MP wide angle lens
- Multi-functional clip

QC-3203 **WAS $34.95**

NOW $24.95

SAVE 28%

EXTERNAL SATA HDD DOCKING STATION - USB 2.0

Docks any 2.5" or 3.5" SATA hard drive for easy transfer of files. Supports hard drive hot swapping.

- Transfer Rate: Up to 30Mbps
- HDD Size: 3.5" - Up to 6TB
  2.5" - Up to 2TB
- 140(W) x 110(D) x 58(H)mm

XC-4690 **ORRP $44.95**

NOW $24.95

SAVE 44%

HDD not included.

ANDROID OTG HUB & CARD READER DOCK

A convenient way to access expanded storage on your Android device. Connects via included micro USB cable.

- 3 x USB 2.0 ports, 1 x SD slot
- 95(L) x 95(W) x 18(H)mm

WC-7765 **WAS $24.95**

Phone not included

NOW $14.95

SAVE 40%

USB TO RS-485/422 CONVERTER

Wire up an RS-485/422 device to the 4 socket terminal block to give your hardware USB connectivity. Surge protected.

- 610mm USB A Male to Male cable incl.

XC-4132 **ORRP $79.95**

NOW $49.95

SAVE 37%

ANDROID PC MIRROR USB CABLE

Displays what you see on your Android device's screen directly on your Windows computer screen.

- Full keyboard & mouse control
- Call & message notifications
- 179mm long

WC-7682 **WAS $59.95**

NOW $34.95

SAVE 41%

2.1A USB PORT POWER BOOSTER

Speed up the charging of your Smartphone and Tablet from your computer that plugs into a standard USB port on your PC. Charges at 2.1A for a fast charge time.

- Input Voltage: 5V
- 45mm long

XC-5700 **WAS $9.95**

NOW $5.95

SAVE 40%

HALF PRICE

BATTERY POWERED PUMP WITH SHOWER HEAD

Use as a direct water pump by detaching the shower head. Made from impact resistant ABS plastic. Weather resistant.

- Hose Length: 2.5m
- Requires 4 x D batteries

YS-2802 **ORRP $29.95**

NOW $14.95

SAVE $15

NEW 2017

$49.95

USB RECORDING PHONOGRAPH AMPLIFIER

Records your vinyl tracks to MP3 using your computer. Power via USB cable or power supply (available separately). Plug and play.

- PC or Mac compatible
- 2 channel recording

AC-1593

NEW 2017

$129

SOLAR POWER METER

Optimises solar panel installations by finding optimum locations for the panels. Expressed as W/m² (Watts per square metre), or BTU/ft² (British thermal units per square foot). Includes carry case.

- Powered by 3 x AAA batteries (included)
- 83(W) x 162(H) x 28(D)mm

QM-1562

80W SLIMLINE LAB POWER SUPPLY

Compact power supply that doesn't take much of your valuable workspace. Includes banana to alligator clamp leads.

- Constant current and voltage options
- 0-16V/5A, 0-27V/3A, 0-36V/2.2A
- 53(W) x 300(D) x 138(H)mm

MP-3842

$149

NEW 2017

MEGAPHONES WITH SIREN

Compact yet powerful. Requires 4 or 8 C-sized batteries.

- Adjustable volume level

10W AM-4041 **$34.95**

25W Detachable microphone. AM-4042 **$69.95**

NEW 2017

FROM $34.95

METAL CABLE TIES

Suitable for use where plastic cable ties won't do. Made from 316 Marine Grade stainless steel. Self-locking head design. Pk 10.

4.6MM X 150MM HP-1182 **$3.95**

4.6MM X 250MM HP-1184 **$4.95**

7.9MM X 200MM HP-1186 **$5.95**

7.9MM X 520MM HP-1188 **$9.95**

NEW 2017

FROM $3.95

LCD SCREEN OPENING TOOL

Suitable for screen removal on most phone, tablet or other smart devices.

- Spring loaded suction pliers
- 160(L) x 75() x 43(mm

TO-2121

NEW 2017

$14.95

LOOM TUBES

Keeps wires tidy and in-place. Made from black flexible PVC.

25MM X 2.0M HP-1801 **$5.95**

40MM X 2.0M HP-1807 **$6.95**

48MM X 2.0M HP-1810 **$7.95**

25MM X 10M HP-1804 **$19.95**

NEW 2017

FROM $5.95

F PLUG REMOVAL TOOL

Designed for inserting or unscrewing stubborn F-Type or BNC connectors.

- Comfortable grip
- Carbon steel
- 255mm long

TO-2000

NEW 2017

$14.95

CABLE TIDY FOR EXTENSION POWER LEADS

No more tangled extension leads! Holds a lead up to 25m long. *Extension lead must be fully uncoiled from the cable tidy before use.*

- Integrated plug & socket clips
- Carry handle

PS-4194

NEW 2017

$4.95

EXTRA LONG CRIMP TOOL FOR NON-INSULATED PLUGS

High quality with comfortable grip and ratchet mechanism to relieve strain on your hands. Ideal for anyone doing frequent or high volume crimping.

- Suits 1.25 to 16mm non-insulated terminals
- 280mm long

TH-1847

NEW 2017

$34.95

TUFF SILICONE TAPE

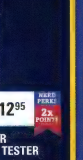
High quality silicone rubber compound. Self-adheres when wrapped under tension. Will even repair a burst radiator hose.

- Won't melt up to +260°C
- Tensile strength of 600psi
- 25mm wide x 3m long

BLACK NA-2630

RED NA-2632

CLEAR NA-2634



NEW 2017

$14.95 ea

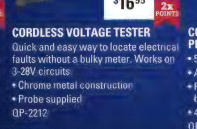
NERD PERKS DOUBLE POINTS

$19.95

NERD PERKS 2x POINTS

CAR BATTERY MONITOR

Plugs into the cigarette lighter socket and gets an instant readout of the car's battery voltage. Works on 12/24V vehicles. QP-2220



$16.95

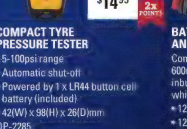
NERD PERKS 2x POINTS

CORDLESS VOLTAGE TESTER

Quick and easy way to locate electrical faults without a bulky meter. Works on 3-28V circuits.

- Chrome metal construction
- Probe supplied

QP-2212



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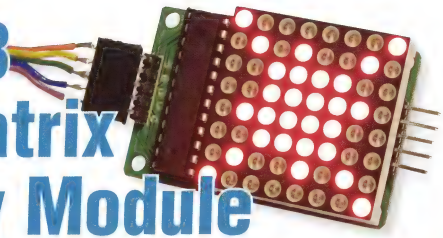
SPI 8x8 LED Matrix Display Module

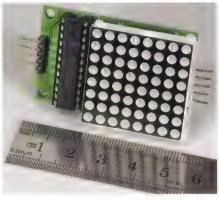


Using Cheap Asian Electronic Modules Part 7: by Jim Rowe

This low-cost module uses a Maxim MAX7219 serial LED display chip and comes complete with a plug-in 8x8 LED matrix display. But the MAX7219 is equally capable of driving an 8-digit 7-segment LED display and its SPI interface allows it to be driven by a micro using only three wires, meaning both the module and the chip are surprisingly flexible.

When I first noticed this type of 8x8 LED matrix display module being offered on eBay and AliExpress, I must confess that I didn't get overly excited. Sure, they were very cheap – but what could you actually use an 8x8 LED matrix display for? All I could think of was for displaying a few pretty patterns. Fun, perhaps, but not all that useful.

Despite this ho-hum first impression, I decided to order a couple of the modules just to see if they had any other uses. And when they arrived, I discovered that they did.



This very cheap module includes the MAX7219 IC and a plug-in 8x8 LED matrix display.

The data sheet for the MAX7219 controller chip is available from Maxim's website (https://datasheets.maxim-integrated.com/en/ds/MAX7219-MAX7221.pdf) and indicates that it has primarily been designed to drive an 8-digit 7-segment LED display. In fact, the ability to drive an 8x8 LED matrix is in many ways just a bonus feature!

Inside the MAX7219

To understand the dual personality of the MAX7219, take a quick look at the block diagram, Fig.1. As you can see, there's more inside this modest-looking 24-pin DIP device than you might have expected.

Down at the bottom, you can see the 16-bit shift register where data and instructions are shifted into the chip from almost any micro, via a standard SPI (Serial Peripheral Interface) bus. Then above the eight least significant bits (D0-D7) is an eight-byte dual-port SRAM, where the display data is stored.

Four more bits, D8-D11, are decoded to determine whether the data in the lower eight bits of the shift register is to be loaded into one of the addresses in the display SRAM (either with or without further decoding), or into one of the control registers to set the chip's operating modes.

Five registers control shutdown, the mode, intensity, scan limit and display test.

Briefly, the purpose of the shutdown register is to blank the display when power is first applied or at a later time, to reduce the power consumption. It can also be used to flash the display on and off, for "alarm" situations. During normal operation, data bit D0 of this register is set to one.

The mode register is used to control whether the data in the SRAM registers for each digit is to be decoded (according to "CODE B") or used as-is. The interesting point here is that the mode register can be set for decoding all eight digits, none of them or virtually any combination in between.

So for driving an 8x8 LED matrix, for example, you wouldn't use the decoding features, while for driving an 8-digit 7-segment display you'd program it to decode all eight registers.

But you could also use it to drive a 6-digit 7-segment display by decoding just those six digits, with the remaining two digit positions either unused or used without

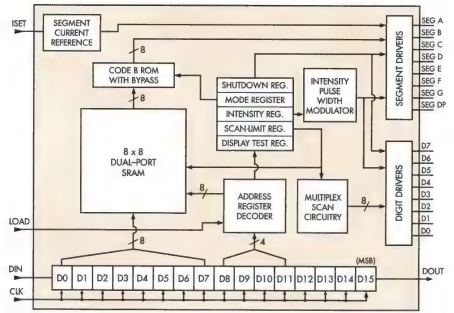


Fig.1: internal block diagram of the MAX7219 IC. The 8-byte dual-port SRAM is used to store the current LED state while the decoder block simplifies the software required to drive a 7-segment display. The segment drivers supply a fixed current determined by the current flow out of the I_{SET} pin and intensity is modulated by PWM applied by those same segment drivers.

decoding to drive other indicator LEDs. So it's quite flexible.

The intensity register provides programmable digital control over the brightness of the LEDs. As you can see from Fig.1, the chip has a segment current reference circuit (at upper left), controlled by the current fed in via the I_{SET} pin (pin 18).

The peak current sourced from the chip's segment driver outputs (upper right) is nominally 100 times the current entering the I_{SET} pin, which is normally connected to the +5V supply rail via a resistor of 9.53kΩ or more. The module shown in the pictures uses a 10kΩ resistor.

At the same time, the value stored in bits D0-D3 of the intensity control register determines the duty cycle of the chip's internal pulse-width modulator and hence the display brightness. The duty cycle is a 4-bit value, meaning that there are 16 different programmable duty cycle/brightness levels, from 1/32 (3%) to 31/32 (97%).

Then there's the scan limit control register, which is basically used to determine how many digits are scanned by the display multiplexing circuitry. This allows the chip to be programmed for any number of display digits between one and eight.

Note though that Maxim warns in the datasheet that if three or fewer digits are selected, the resistor connected to the chip's I_{SET} pin should be increased in value to reduce the power dissipation in the digit drivers.

Finally, there's the display test control register, which can be used to switch between normal operation and the test mode, where all segments are lit in order to test the display itself.

To help you put all of these functions of the MAX7219 into perspective, Fig.2 summarises the decoding of register address bits D8-D11 while Fig.3 shows the significance of data bits D0-D7 when segment decoding (ie, "CODE B") is enabled (A) or decoding is disabled (B).

Driving the 8x8 LED matrix

So that's a quick run-down on the MAX7219 device and its internal working. Fig.4 shows the full circuit for the module as it arrives and it has everything needed to drive the 8x8 LED matrix directly from a micro like an Arduino or a Micromite.

There's very little to the module apart from the MAX7219 (IC1), the 8x8 LED matrix and the two 8-pin connectors (CON2 and CON3) used to join them together.

There are two 5-pin SIL connectors; one used for the supply and serial bus inputs (CON1) and the other for the matching outputs (CON4) used for daisy-chaining further modules, plus the 10kΩ resistor connected to IC1's I_{SET} pin and a pair of bypass capacitors on the 5V supply line, one 100nF and one 10μF electrolytic.

Programming it to produce interesting patterns turns out to be fairly straightforward, as we'll see shortly. But before we do so, you'll recall that I mentioned earlier that the MAX7219 was originally intended for driving 7-segment LED displays of up to eight digits.

Driving 8-digit 7-segment displays

This configuration is shown in Fig.5, with a pair of 4x7-segment displays wired to CON2 and CON3 of the

DON'T CARE				REGISTER ADDRESS BITS				DATA BITS								
D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0	
X	X	X	X	0	0	0	0									= NO OP (X0 hex)
X	X	X	X	0	0	0	1									= DIGIT 0 (X1 hex)
X	X	X	X	0	0	1	0									= DIGIT 1 (X2 hex)
X	X	X	X	0	0	1	1									= DIGIT 2 (X3 hex)
X	X	X	X	0	1	0	0									= DIGIT 3 (X4 hex)
X	X	X	X	0	1	0	1									= DIGIT 4 (X5 hex)
X	X	X	X	0	1	1	0									= DIGIT 5 (X6 hex)
X	X	X	X	0	1	1	1									= DIGIT 6 (X7 hex)
X	X	X	X	1	0	0	0									= DIGIT 7 (X8 hex)
X	X	X	X	1	0	0	1									= DECODE MODE (X9 hex)
X	X	X	X	1	0	1	0									= INTENSITY (XA hex)
X	X	X	X	1	0	1	1									= SCAN LIMIT (XB hex)
X	X	X	X	1	1	0	0									= SHUTDOWN (XC hex)
X	X	X	X	1	1	1	1									= DISPLAY TEST (XF hex)

Fig.2: data is sent to the MAX7219 over a serial bus, 16 bits at a time. This table shows how bits 8-11 determine which register is written to, while bits 0-7 contain the new data for that register. With bits 8-11 set to a value between 1 and 8, one of the entries in the dual-port SRAM is updated while values of between 9 and 12 or 15 are used to write to one of the five control registers.

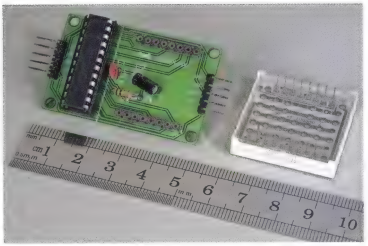
(A) WHEN DATA BIT 'CODE B DECODE' MODE IS SELECTED

DATA BITS								
D7	D6	D5	D4	D3	D2	D1	D0	DECODED 7-SEGMENT CHARACTER
[DP]	X	X	X	0	0	0	0	(X0 hex) → 0
[DP]	X	X	X	0	0	0	1	(X1 hex) → 1
[DP]	X	X	X	0	0	1	0	(X2 hex) → 2
[DP]	X	X	X	0	0	1	1	(X3 hex) → 3
[DP]	X	X	X	0	1	0	0	(X4 hex) → 4
[DP]	X	X	X	0	1	0	1	(X5 hex) → 5
[DP]	X	X	X	0	1	1	0	(X6 hex) → 6
[DP]	X	X	X	0	1	1	1	(X7 hex) → 7
[DP]	X	X	X	1	0	0	0	(X8 hex) → 8
[DP]	X	X	X	1	0	0	1	(X9 hex) → 9
[DP]	X	X	X	1	0	1	0	(XA hex) → –
[DP]	X	X	X	1	0	1	1	(XB hex) → E
[DP]	X	X	X	1	1	0	0	(XC hex) → H
[DP]	X	X	X	1	1	0	1	(XD hex) → L
[DP]	X	X	X	1	1	1	0	(XE hex) → P
[DP]	X	X	X	1	1	1	1	(XF hex) → (blank)

(B) WHEN DATA BIT 'NO-DECODE' MODE IS SELECTED

DATA BITS								
D7	D6	D5	D4	D3	D2	D1	D0	
[DP]	A	B	C	D	E	F	G	CORRESPONDING SEGMENTS WITH NO DECODING

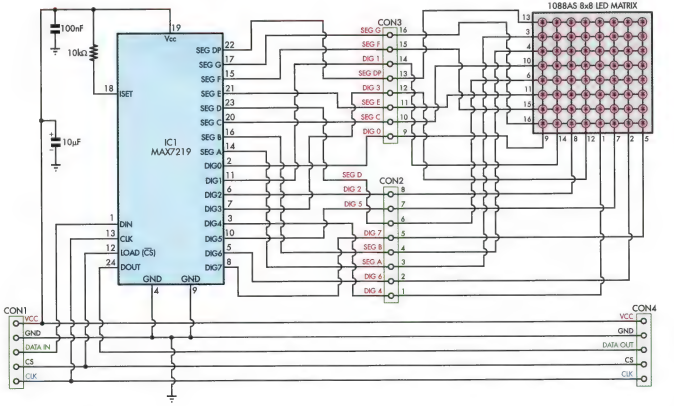
NOTE: DECODE/NO-DECODE MODE CAN BE SELECTED INDEPENDENTLY FOR EACH OF THE EIGHT DIGITS, USING THE DECODE REGISTER



Above is the layout of the module without the 7-segment display and below in Fig.4 is the matching circuit diagram.

Fig.3 (left): when "Code B" decoding is active for a segment, the lower four bits of the value for that segment forms a lookup table for one of 16 possible 7-segment display configurations, as shown at right. The top bit determines whether the decimal point is lit. Compare this to (B) at bottom, where decoding is not active and the eight bits in SRAM control the segment drivers directly.

Fig.4 (below): the circuit of a typical pre-built 8x8 LED matrix module with MAX7219 driver. A photo of this type of module is shown above. There's virtually nothing to it, just the LED matrix display module, the MAX7219 IC and some connectors to join them together and to provide connections to the microcontroller and optionally, more daisy-chained LED displays.



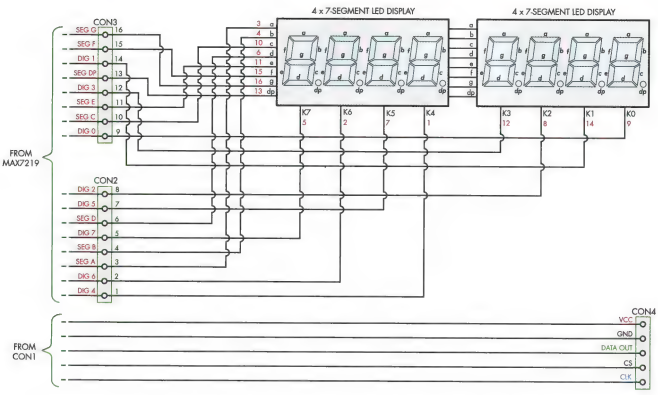


Fig.5: the circuit of a typical pre-built 8-digit 7-segment common cathode LED display using a MAX7219. Pre-built modules for this configuration are also available. We haven't shown the IC itself, as its configuration is identical to that of Fig.4 – all that's changed is that in place of the 8x8 LED matrix are two 4-digit 7-segment displays with the anodes wired in parallel.

module instead of the 8x8 LED matrix. Note that for space reasons, we haven't shown the MAX7219 chip or the rest of the module circuitry to the left of CON2 and CON3 in Fig.5, but these are all exactly the same as in Fig.4.

In fact, the only changes needed to drive a pair of 4x7-segment displays instead of an 8x8 LED matrix with the MAX7219 module are in terms of software rather than hardware.

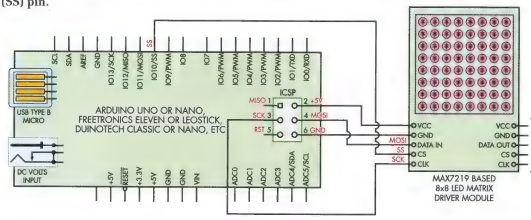
Specifically, it's just a matter of enabling decoding for all eight digits, instead of disabling it, as required for driving the 8x8 LED matrix. Which leads us on to hooking the MAX7219 module up to popular micros and programming it to display what you want.

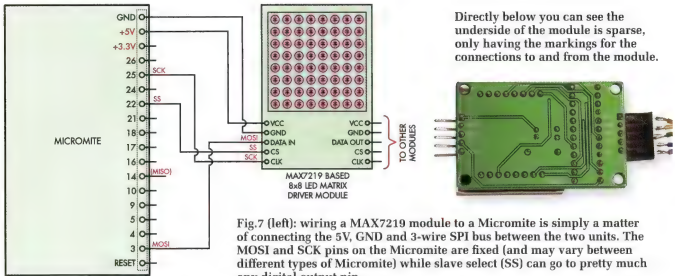
In fact, not only is it possible to drive an 8-digit display using a MAX7219, pre-built modules are available on eBay and AliExpress, etc. These incorporate a PCB with an SMD MAX7219 on the back and two 4-digit 7-segment displays plugged into header sockets on the front. Like the 8x8 matrix displays, they have 6-pin connectors at each end to wire up to your micro and also allow daisy chaining.

Driving them from an Arduino

As shown in Fig.6, it's quite easy to

Fig.6: connecting either type of MAX7219-based module to an Arduino is easy. Simply wire up the SPI pins and power supply to the ICSP header on the Arduino and the CS pin to a free GPIO – ideally IO10 which is the hardware slave select (SS) pin.





Directly below you can see the underside of the module is sparse, only having the markings for the connections to and from the module.

Fig.7 (left): wiring a MAX7219 module to a Micromite is simply a matter of connecting the 5V, GND and 3-wire SPI bus between the two units. The MOSI and SCK pins on the Micromite are fixed (and may vary between different types of Micromite) while slave select (SS) can go to pretty much any digital output pin.

connect these modules up to almost any Arduino or Arduino clone, by taking advantage of the fact that most of the connections needed for interfacing to an SPI peripheral are made available on the 6-pin ICSP header fitted to most Arduino variants.

The connections to the ICSP header are fairly consistent over just about all Arduino variants, including the Uno, Leonardo and Nano, the Freetronics Eleven and LeoStick, and the Duinotech Classic or Nano.

In fact the only connection that's not available via the ICSP header is the one for SS/CS/LOAD, which needs to be connected to the IO10/SS pin of an Arduino Uno, Freetronics Eleven or Duinotech Classic as shown in Fig.6.

With other variants you should be able to find the corresponding pin without too much trouble and even if you can't, the pin reference can be changed in your software sketch to match the pin you do elect to use.

Driving them from a Micromite

It's also quite easy to drive these modules from a Micromite, using the connections shown in Fig.7.

By connecting the MOSI, SCK and SS/LOAD lines to Micromite pins 3, 25 and 22 as shown, MMBasic's built in SPI protocol commands will have no trouble in communicating with the module.

So that's the basic story regarding the hardware side of the MAX7219 based module which can drive either an 8x8 LED matrix array or eight 7-segment LED displays.

Before we finish, a few words are in order regarding the software side, ie, how to write programs to get the module to display what you want.

Writing the software

The basic idea here is that when your program starts up, it needs to carry out a number of set-up tasks. These are:

- Declare the micro's pins that are going to be used by the SPI interface and set them to their idle state (normally high).
- Start up the SPI interface, with its settings configured for a clock rate of say 5MHz, the data to be sent MSB (most significant bit) first and using clock/data timing mode 0. If possible, it should also be set for the data to be exchanged in 16-bit words rather than bytes.
- Send the initialisation commands to the MAX7219 to set up its five control registers: shutdown, decode mode, intensity, scan limit and display test.

After these tasks have been done, you should be able to send out the actual display data for each of the 8-digit display addresses in the MAX7219's SRAM. And if the display is to be a dynamic one, you can send out revised data at the appropriate times.

To help you understand what's involved in writing your own programs for the module, I have written a couple of simple example programs which repeatedly display an expanding star pattern on the 8x8 LED matrix array (you can see the fully expanded star on the lead photo).

One of these programs is written for Arduino and is called "sketch2_for_Testing_MAX7219.ino". The other is written for the Micromite, and is called "MAX7219 LED array Star.bas". Both of these programs are available for download from the SILICON CHIP website (www.siliconchip.com.au).

Both programs simply blank the display for a second or so, then cause a small square pattern to appear first in the centre of the array and then expand out fairly quickly to form a star, with its tips at the four corners of the array. The expanded star remains visible for about three seconds before the array is blanked again and the sequence repeats.

It's all quite simple, but either program should give you a reasonably clear guide regarding how to use the MAX7219 display driver module in your own projects.

I've tried to provide a lot of explanatory comments in both programs, to help in this regard. SC

Ultrasonic Anti-Fouling Unit for Boats, MkII

By Leo Simpson & John Clarke

Part 2: building it and fitting it to your boat

If you own a boat which spends its time in the water, you'll know what a (costly!) bane marine growth can be. Last month we introduced our new, improved Ultrasonic Anti-Fouling Unit which can significantly reduce the amount of growth on your hull – and increase the interval between slipping and cleaning.

Ultrasonic anti-fouling won't completely eliminate marine growth but it can minimise it. As we explained last month, the tiny organisms which like to attach to your hull will be actively discouraged from, well, attaching. And the larger marine plants which feed on them will go elsewhere.

That's the theory – and using our previous Ultrasonic Anti-Fouling Unit (Sept, Nov 2010) as a yardstick, the theory is well borne-out in practice. Growth-cleaning intervals can easily be doubled and even then there is less growth into the bargain, as our photos last month showed.

There are only a few hull types which aren't suitable (which we covered last month) and, somewhat surprising to us, ultrasonic anti-fouling is effective in fresh water as well as salt.

We confidently expect this new, higher performance Ultrasonic Anti-Fouling Unit to be even more effective than the previous model and well worth the investment in money and time to build it and fit it to your boat.

Construction

The Ultrasonic Anti-fouling MkII circuitry is built on a double-sided, plated through PCB coded 04104171 and measuring 158.5 x 110.5mm. This is mounted inside an IP56 sealed polycarbonate enclosure with a clear lid, measuring 171 x 121 x 55mm.

Use the PCB overlay diagram, Fig.5, as a guide during construction. You can build the unit to drive one or two transducers. For the single transducer version, CON2, T2, Q3, Q4, ZD3, ZD4, D3, D4, D6 and all associated resistors and the 1nF 2kV capacitor are not required.

All parts for the second transducer are depicted on the area of the circuit diagram (published last month) shaded yellow. Similarly, the component overlay diagram of Fig.5 is shaded yellow to show the extra parts for the second transducer. So if you are going to build a one-transducer version, ignore any discussion of these particular parts in the construction procedure.

Assembly can begin by installing the resistors and optional PC stakes. Table 1 shows the resistor colour codes but you should also check each resistor using a digital multimeter (DMM).

Note that the 220kΩ and 130kΩ resistors near the neon lamps are first covered in a 10mm length of 3mm diameter heatshrink tubing before being fitted to the PCB, to reduce the chance of electric shock if you make accidental contact with these leads. Use a hot air gun to shrink the tubing after the resistors have been soldered in place.

PC stakes can then be installed for TP1 & TP2 and the

Unlike the earlier design, which required the ultrasonic transducer to be "potted", the MkII version uses the Soanar YS-5606 (from Jaycar) which comes already potted.

The Ultrasonic Anti-Fouling Unit can be built to drive one or (as shown here) two ultrasonic transducers. If your craft is less than 8m long, you should be able to get away with one – in which case, the majority of components on the bottom right of this photo are not installed (see below).

two TP GND points. Following these, mount the diodes, which must be orientated as shown in Fig.5. Note that there are several different diode types: 1N5819s for D1-D4 and D10; UF4007 for D5 and D6; 1N4004 for D7; BAT46 for D8 and D9; and 5.1V zener diodes for ZD1-ZD4.

As with the resistors, diodes D5 and D6 should be covered in 3mm heatshrink tubing before installation.

Next, install the 18-pin socket for IC1, taking care to orient it correctly. Leave IC1 out for the time being. Q1-Q5 can be fitted next. These mount horizontally onto the PCB and are secured with a 6-10mm M3 screw, star washer and nut. Bend the leads at right angles so they can be inserted into the allocated holes. Secure the tab of each Mosfet before soldering its leads.

You can then fit regulator REG1, again orientated as shown in Fig.5. Bend its leads to fit the PCB pads and solder it in place. Then proceed to mount the capacitors. The electrolytic types must be oriented with the polarity shown.

Make sure the 1nF MKT capacitor is placed in the position just above and to the left of ZD1. The remaining MKT capacitors are 100nF. The 1nF 2kV capacitors are installed near T1 and T2.

The screw terminals can go in next. The 3-way terminals

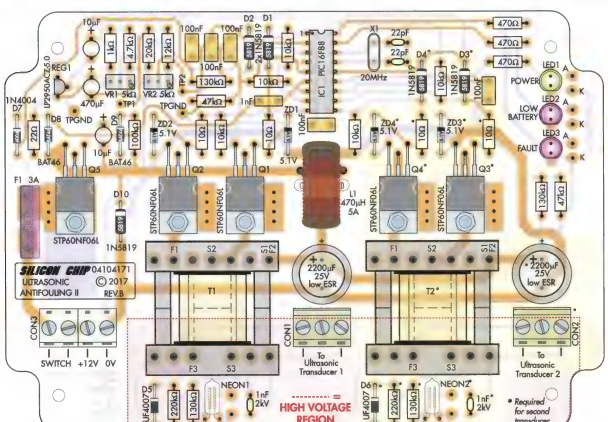


Fig.5: component overlay for the two transducer version of the Ultrasonic Anti-Fouling Unit, MkII. To build the single transducer version, simply leave out all components in the light yellow section of the PCB – Q3, Q4, ZD3, ZD4, D3, D4, D6, NEON2, T2, CON2 and associated resistors/capacitors. Note the area of the PCB with a dashed red border/light pink background has high voltages on both the tracks and component leads when operating.

Here's what the PCB looks like mounted inside the waterproof polycarbonate box with external connections made . . .

for CON1 and CON2 are modified to remove the centre terminal, to increase the voltage rating between the two outer contacts.

Fully unscrew the centre screw and prise it out of the plastic connector. The central contact will slide out of the housing. The screw terminals are installed with the lead entry toward the lower edge of the PCB.

CON3 is made up of two 2-way screw terminals dovetailed together. Install it with the lead entry also toward the lower edge of the PCB.

Insert the leads of inductor L1 into the PCB and secure it in place with a cable tie that wraps around the lower part

STEP-BY-STEP FITTING GUIDE IN PICS

A: Roughen the bottom of the 50mm flanged nut with some coarse sandpaper. This is to give a good "key" for the adhesive to ensure it won't vibrate loose when fixed to the boat hull.

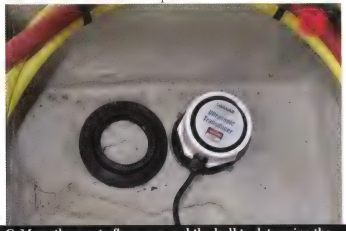
B: It's important that glue doesn't get into the thread, where it would clog it up. Smear a good coating of Vaseline right around the threads – make sure it doesn't get on the bottom of the flange.

. . . and here it is with the lid fitted, with the front panel label mounted inside for protection from the marine environment.

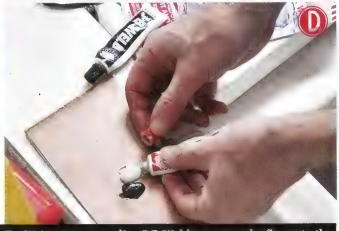
of the toroid and through the two holes in the PCB. Once secured, solder the leads in place. The fuseholder for F1 can then be fitted. This requires good solder joints so use a hot soldering iron and pre-heat the fuse holder terminals. When applying solder, make sure it has adhered to both the terminals and the PCB pads.

Crystal X1 can be installed next, followed by trimpots VR1 and VR2. Orient the adjustment screws as shown so that clockwise rotation will give a rising voltage adjustment.

The LEDs are fitted next. The green LED (LED1) is for Power indication and the two red LEDs for Low Battery and Fault indication (LED2 and LED3). The anodes are the



C: Move the empty flange around the hull to determine the best transducer mounting position. When you're happy with your choice, roughen the surface as you did the black flange – for the same reason.



D: We're recommending J-B Weld to secure the flange to the hull. It's not that easy to buy (but Jaycar stores do stock it – Cat NA1518) and it's not real cheap – but it sticks like the proverbial.

You'll need each of these to mount the transducers in your boat: some Vaseline (petroleum jelly), some Fix-a-tap waterproof lubricant (available at plumbing suppliers) and some J-B Weld two-part epoxy (available at Jaycar stores). We do not recommend any other epoxy glues – J-B Weld really holds on even with a boat hull's vibration and stress!

longer of the two leads and these are inserted in the LED holes marked "A" on the PCB.

We positioned our LEDs so the tops were 20mm above the PCB for better visibility. You could place these higher if you wish, up to 40mm above the PCB (assuming the leads are long enough).

Fit the neon indicators after slipping 5mm lengths of 6mm diameter heatshrink tubing over the leads for insulation.

Initial testing

Before installing the transformers, do some tests on the PCB. It is safer to work on the PCB without the transformers installed, since high voltages are not being produced. Initially, adjust VR1 fully clockwise by rotating the adjustment screw by 10 turns. This sets the low battery shut-down at its highest voltage.

Insert the fuse and place a short length of wire between the switch terminals for CON3. Make sure IC1 is **not** in its socket and connect 12V across the 0V and +12V terminals of CON3.

Check that the voltage between pins 5 and 14 of the IC1 socket is close to 5V (4.975-5.025V). Switch it off, insert IC1, then re-apply power. The power LED should be lit and voltage across the 2200µF capacitors should rise up to around 12V after a few seconds.

You can adjust VR1 for the required low battery voltage setting. This is done by monitoring the voltage between TP1 and TP GND for 1/10th the required voltage. If you aren't sure, adjust for 1.15V (a cut-out voltage of 11.5V). Then set the hysteresis by adjusting VR2 and monitoring the voltage between TP2 and TP GND. If unsure, set this to 0.5V.

You can check the operation of the low battery cut-out feature now if you have access to an adjustable supply. After power up, wait about 30 seconds until the power LED flashes on and off. This indicates that Mosfets Q1-Q4 are now being driven.

Slowly reduce the supply voltage until the power LED switches off and the low battery LED flashes and note the voltage. Battery voltage readings are averaged over about 10 seconds and so you need to wait this long each time after dropping the supply voltage.

Once low battery shut-down has occurred, assuming it's at the expected supply voltage, increase the supply until the circuit restarts with the power LED lit, as before, waiting 10 seconds between each adjustment. Readjust VR1 and VR2 if needed.

Note that during low-battery shut-down (and while ever the fault indicator is showing), VR1 and VR2 are powered down and so these cannot be set correctly. You can only successfully set VR1 and VR2 during normal startup, when the power LED is continuously lit, or during normal operation when the power LED is flashing.

Finishing construction

Now switch off power and wait until the power LED goes out. Then wait for the low battery LED to stop flashing. This can take up to 30 seconds. Now check voltage across one of the 2200µF low-ESR capacitors. Only install the transformers when the capacitor voltage has dropped to below 1V.

Note that the primary side of the transformer has seven pins and the secondary side has six pins, so it can only go in one way. That completes the PCB assembly.

The front panel label can be downloaded from our website as a portable document file (PDF). You can print it out onto plain paper or photo paper. The panel label can also be used as a template for drilling a hole for the power switch. The label is positioned in the upper left corner of

E: Apply a good layer of mixed glue all over the roughened base of the flange, again making sure you don't get any on the thread. You have quite a while before it starts to cure so take your time!

F: It's almost inevitable that there will be some J-B Weld oozing out from under the flange. The secret: apply only as much pressure as is really needed to ensure the glue spreads right around, then wipe any excess off before it sets.

the lid and goes inside the lid so it is protected from water.

It can be attached with a mist of spray glue, with clear tape or with a clear silicone sealant covering the top of the label. The hole for switch S1 is cut out of the panel label using a sharp hobby knife.

Holes are required in one side of the box for the power lead cable gland and for the sockets for connection to the ultrasonic transducers.

Secure the PCB into the box with M3 x 6mm screws before mounting the sockets and cable gland for the power lead. Wire up the sockets, switch and supply leads as shown in Fig.5 and the internal photos. Use 70-80mm lengths of mains-rated wire from CON1/CON2 to the panel-mount sockets. Insulate the connections at the socket end with heatshrink tubing. Attach the switch to CON3 and wire a suitable length of power cable that will go to the battery, to CON3.

When fitting the lid, use the neoprene seal and four stainless screws which came with it.

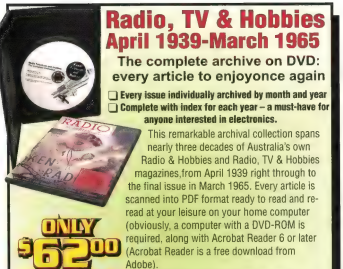
Installation in the boat

For installation, you need a few extra parts, including a 50mm BSP flanged back-nut for each transducer. This is secured to the hull using J-B Weld 2-part epoxy (Jaycar NA-1518), providing an anchor for the transducer that screws into the flanged back-nut

Additionally, "Fix-A-Tap" waterproof lubricant is required. The back-nut and lubricant are available from plumbing suppliers. You will also need a tub or tube of Vaseline (aka petroleum jelly).

The Ultrasonic Anti-fouling MkII case needs to be mounted on a bulkhead or other position where it is not likely to be splashed or immersed in any water which may be in the bilge. The encapsulated transducer or transducers must be installed inside the hull. For a single transducer, mount it near the running gear (ie, propellers and rudders). Where two transducers are used, one is placed near the running gear and the other toward the bow of the boat. Catamarans will require one transducer per hull, both placed near the running gear.

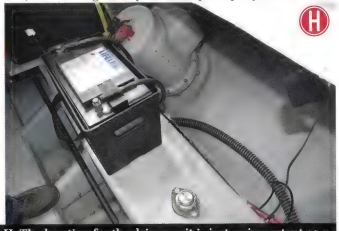
First, you must find a suitable flat section of the hull and on many boats – this will not be easy. Try temporarily positioning the flanged back-nut in a number of positions to get the best spot.



Having found a good position, roughen the face of the flanged back-nut using coarse sandpaper and a sanding block, as shown in photo A. You want a good "key" for the epoxy resin. Also use the sandpaper and sanding block to thoroughly scour the hull position where the flange is to be mounted. Photo C shows the flanged back-nut temporarily in position on the hull after it has been sanded.

It is essential that the mounting area for the flange is clean and dry, and free from dust and grease. Also, there should be no possibility of exposure to bilge water while the epoxy resin is curing. When ready, mix a quantity of the J-B Weld High-Temperature 2-part epoxy resin. Do not

G: Once set (24 hours +), the transducer assembly is screwed into position with a good big dollop of Fix-A-Tap lubricant on the face. But before doing so, wind it anti-clockwise a number of turns.

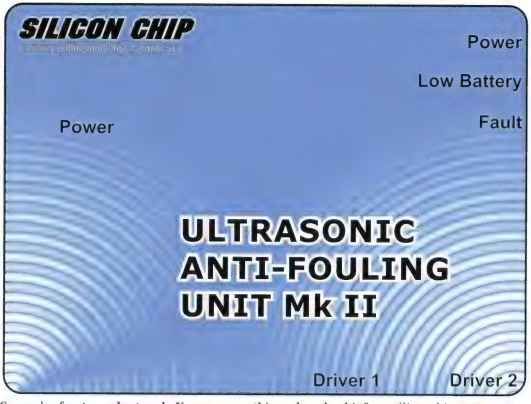


H: The location for the driver unit is just as important as the transducer. It must be one which can NEVER interfere with any boat operation and one which won't be stepped on if you need to get into the area.

use Araldite or any other epoxies. We want to be sure of a reliable long-term bond to the hull which won't let go with constant ultrasonic, engine and propeller vibration. [see Photo E below].

Apply a liberal coating of petroleum jelly (or Vaseline) to the thread of the flanged back-nut, as in pic B. We don't want any epoxy resin to adhere to the threads, otherwise, the flange will not be usable. Apply the mixed epoxy resin to the roughened surface of the flange, as in photo E. Then press it down onto the previously prepared section of the hull. Leave it to set for 24 hours, or longer in cold temperatures. Refer to the instructions supplied with the J-B Weld adhesive.

Some adhesive will probably ooze out from under the flange. This doesn't matter too much, apart from aesthetics. Inside, though, it should be carefully cleaned away without getting it on the thread of the flanged back-nut. That's so that the transducer (when fitted) will not sit proud of the hull.



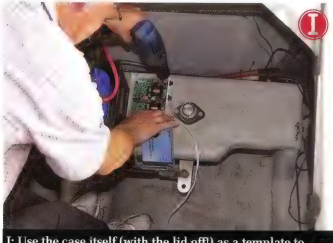
Same-size front panel artwork. You can copy this or download it from siliconchip.com.au (as a PDF), print it and then secure it to the underside of the case clear lid, to protect it from moisture and damage. A mist of spray glue (available at stationery stores) will secure this to the lid. The only hole required is that for the power switch – cut this with a sharp knife.

Installing the driver unit

The next step is to install the ultrasonic driver unit. Its IP65 plastic case has internal provision for four mounting screws, near the screws which attach the lid. To fit them, you need to remove the transparent lid of the case and position the unit in the spot where it is to be mounted. Preferably, it should be on a vertical bulkhead above the waterline, say between the engine compartment and the lazarette. It is most important that the ultrasonic driver unit is mounted above any likely spray or splashes from water in the bilge.

On no account should you drill holes in the hull to mount the ultrasonic driver. Photo I overleaf shows the ultrasonic driver being mounted in place. **You must use AS316-grade stainless steel screws;** anything else will quickly corrode. Having mounted the ultrasonic driver in place, you are ready to install the encapsulated transducer or transducers to their flanged back-nut

Inevitably, this will involve running cable through parts of the boat structure.



I: Use the case itself (with the lid off!) as a template to mark your drilling positions, then move the case and drill the holes to mount the driver electronics.

J: Use good quality marine stainless steel screws for securing the case to its mounting position. A power screwdriver is a good idea here: we didn't have the right bit and screwing into the fibreglass was really tough going.

If you can run the cable next to existing cable, so much the better. Lace or tie the cable into position where possible. It should not be allowed to flap about or hang in loose loops.

Again, remember that boats experience severe vibration and we don't want the cable to fail in the long term; see photo K below.

You may have to drill holes in bulkheads to run the transducer cable through. If so, smooth off rough edges and fit suitable grommets to protect the cable from chafing.

When the J-B Weld has cured, we can return to the transducer mounting. First, liberally coat the face of the encapsulated transducer with a non-hardening grease. We suggest "Fix-A-Tap" waterproof lubricant which can be readily obtained from hardware stores. This is applied to fill any voids when the transducer housing is screwed down into the flange.

Before screwing in the transducer, twist it anti-clockwise for the same number of turns as it takes to screw it in so that when the transducer is installed, the cable is in its natural (untwisted) position.

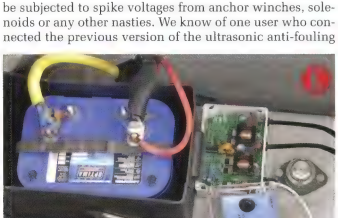
Do not over-tighten it but make sure that it is tight enough that it is not likely to shake loose over time. Then make sure that the transducer cable is neatly routed and cannot possibly interfere with the operation of any moveable parts such as the rudder gear.

Finally, you need to make the supply connections to the house battery. Again, lace and anchor the supply cable securely. There is no need for an in-line fuse since there is already a 3A fuse within the Ultrasonic Anti-fouling MkII unit.

Must nots

The electrical systems of boats are not nice places for electronic devices. Very high spike voltages can be generated by solenoids, electric winches, starter motors and particularly from bow and stern thrusters which pull very high currents.

With this in mind, you must connect to the ultrasonic anti-fouling unit directly to the terminals of the house battery and not somewhere else in the harness where it might be subjected to spike voltages from anchor winches, solenoids or any other nasties. We know of one user who connected the previous version of the ultrasonic anti-fouling unit across the starter motor terminals – it did not live long!



K: after mounting, connect to an appropriate battery (one that receives shore power or solar panel charging). Dress the leads so that they can't move around (remember that there is severe vibration present).

More importantly, don't even think about running your ultrasonic anti-fouling unit from the batteries for your bow and stern thrusters. On our own prototype unit, our trusty boat electrician thought he was doing us a favour by connecting the anti-fouling unit to the much larger battery for the stern thruster. We don't know how long it lasted before the supply input components failed. Don't do it!

Note that since the unit is intended to run continuously, the battery needs to be kept charged. Preferably, a 3-state charger should be used powered via mains power (if shore power is available), solar panels or a wind turbine.

When power is applied to the Anti-fouling unit, the green power LED should light. After about 30 seconds, this LED should flash and the neon indicators will flash in unison, to indicate that the transducer(s) are being driven.

Where do you get a kit of parts?

The Ultrasonic Anti-fouling Unit MkII has been developed in conjunction with Jaycar Electronics and will not be available from any other suppliers.

Kits should be available from all Jaycar stores and some resellers from this month. Pricing is as follows:

SINGLE TRANSDUCER KIT: (Cat KC5535) – $249.00*

SECOND TRANSDUCER KIT: (Cat KC5536) – $169.00**

* Single transducer kits contain only those components necessary to build a single transducer unit. This includes the waterproof case and one transducer. They DO NOT include J-B Weld, Vaseline or waterproof lubricant

**Second transducer kits contain the second transducer plus Q3, Q4, ZD3, ZD4, D3, D4, D6, NEON 2, T2, CON2 and associated resistors/capacitors, as shown on the circuit and PCB.

Ultrasonic Anti-fouling FAQs

Q: How big a boat can the unit handle?

A: The single transducer design and driver presented here is suitable for boats up to 8 metres long. Longer boats, say up to 14 metres, will require two transducers. Boats bigger than 15 metres, say up to 20 metres, will require at least three and maybe four transducers and drivers.

Catamarans up to 10 metres long will require a separate transducer and driver unit for each hull.

Q: Do I need to cut a hole in the hull for the transducer?

*A: You must **not do this** or do anything else to prejudice the integrity of the boat's hull. This is particularly important for boats with fibreglass or composite (sandwich) construction. The encapsulated transducer is mounted on a flat surface inside the hull. For a boat up to 8 metres, the transducer should be mounted near the running gear (ie, propellers & rudders) so that it offers maximum protection from marine growth.*

For longer boats, fit one transduder near the running gear and the other closer to the bow.

Q: Is ultrasonic anti-fouling suitable for all boats?

A: No. Ultrasonic anti-fouling relies on one or more transducers mounted inside the hull to excite it at various frequencies in order to disrupt the cell structure of algae. It works well with metal hulls such as aluminium and with fibreglass hulls. It does not work with timber hulls as the timber is not a good conductor of ultrasonic energy. The same comment applies to ferro-cement or fibreglass hulls with a balsa sandwich or other composite construction (eg, closed-cell PVC foam).

Q: Is it necessary for the boat's hull to be cleaned of marine growth and conventionally anti-fouled before the ultrasonic anti-fouling system is installed?

A: Yes. Ultrasonic anti-fouling is unlikely to kill shell fish or molluscs already attached to the hull. Nor will it cause them to detach from the hull. Hence, there is no alternative to having the hull water-blasted to clean off all existing marine growth.

And if it is already on the slips for such cleaning and other maintenance such as servicing outboard legs and replacing sacrificial anodes, it makes sense to have conventional anti-fouling paint applied, although this may be regarded as optional.

We should also emphasise that, no matter how effective ultrasonic anti-fouling may be in keeping the hull clean of marine growth, it will still be necessary to do regular maintenance such as the servicing of outboard legs (in case of boats with inboard/outboard motors) and replacing sacrificial anodes.

Q: Does the ultrasonic anti-fouling unit present a risk of electric shock?

A: No. As stated in the circuit description, the ultrasonic transducer is driven with peak voltages up to 800V. If you make direct contact with the circuit or the ultrasonic transducer there is a very high probability that you will receive a severe electric shock. That is why the transducer itself must be completely encapsulated in a plastic fitting. This prevents anyone from getting a shock from the system.

Q: Will ultrasonic anti-fouling keep propellers, rudders and other "running gear" free of marine growth or is it still necessary to use anti-fouling compounds such as PropSpeed?

A: Ultrasonic anti-fouling will help keep props and rudders free of marine growth but it won't necessarily be the complete answer. Our experience is that PropSpeed is still worthwhile.

Q: Does ultrasonic anti-fouling cause increased electrolytic leakage currents (electrolysis) and thereby increase corrosion on boats?

A: No. The ultrasonic transducer and driver unit are installed entirely within the hull of the boat and the ultrasonic transducer itself is transformer driven and is completely encapsulated to provide a high degree of insulation. There should be no leakage currents at all.

Q: Is ultrasonic anti-fouling equipment likely to cause damage to the hull of a boat, especially those of fibreglass construction? Will it cause osmosis or de-lamination?

A: We know of no research into this topic and while it could be suggested that the continuous, albeit very low-power, ultrasonic vibration of the hull could lead to de-lamination, such ultrasonic vibration is extremely low in amplitude compared with the severe hull vibration caused by propellers and diesel or petrol motors when boats are operating at high power, especially when "on the plane".

Since we published our first Ultrasonic Anti-fouling unit in 2010, we have had a great deal of feedback and lots of questions. Here are the answers.

Furthermore, hulls are placed under very high stresses when boats are being pounded by heavy seas or are repeatedly slammed though waves or hitting wakes of other boats at speed.

Many older fibreglass boats, say more than 25 years old, can be subject to osmosis and de-lamination. Repairs are routine but expensive to carry out and the boat must be out of the water for many months to ensure that any water trapped in hull laminations is removed.

If a boat was fitted with ultrasonic anti-fouling and after years of use, there is subsequent evidence of hull osmosis or de-lamination, it would be impossible to determine if it were caused by normal wear and tear or other causes.

Ultrasonic anti-fouling is routinely fitted to brand new boats but anyone contemplating such an installation would be wise to check that hull warranties are not invalidated. We make no warranties that ultrasonic anti-fouling does not cause hull damage.

Q: Does ultrasonic anti-fouling harm fish or marine mammals?

A: This system causes no harm to fish or to marine mammals. Fish cannot hear it and while marine mammals certainly can perceive and respond to ultrasonic signals, they are not harmed in any way by the relatively low power levels which are likely to be radiated by the hull of the boat.

Furthermore, the signal levels are much lower than those directly radiated by depth sounders and fish finders.

Q: Will my boat batteries be damaged by the ultrasonic driver unit?

A: No. The ultrasonic driver circuitry described last month incorporates battery protection. If the battery is discharged to 11.5V, the circuit is disabled and will not resume operation until the battery is recharged.

However, since the ultrasonic anti-fouling driver is designed to operate continuously, the battery supplying it will need to be on permanent float charge. This will require 230VAC shore power if you are fortunate enough to have your boat in a pen or marina berth.

If your boat is on a swing mooring or is otherwise without shore power, then a solar panel and suitable charger will be needed to keep the battery up to charge.

Q: How big a solar panel will be required to keep the battery sufficiently charged?

A: The continuous power drain of the ultrasonic driver is about 5W or less for one transducer and less and 9W for a 2-transducer version, depending on the actual supply (the peak powers applied to the transducers are much higher, at around 40W or more).

To provide this level of power on a continuous basis, you will need a solar panel installation of at least 20W. Many boats on swing moorings would already have such a solar panel but it would need to be augmented by at least another 20W to be sure that the battery is fully charged during periods of bad weather or in winter when there are less hours of sunlight.

Q: Will I be able to hear the ultrasonic anti-fouling unit in operation, especially at night when the water is very still?

A: Probably not. Unless you are a bat(!), you cannot hear ultrasonic frequencies directly. However, the transducers and the driving transformers do emit high frequencies and clicks at low levels. These are actually sub-harmonics of the ultrasonic signals and are most evident as the frequencies are continuously shifted up and down over the operating spectrum.

However, once the unit is installed, you will only be able to hear these sounds, if at all, by placing your ear directly over the ultrasonic driver or over the transducer. You might also be able to feel some slight vibration of the transducer itself.

On the other hand, divers underneath boats fitted with ultrasonic antifouling often report unpleasant pressure sensations in the ears. So if you have a diver underneath the boat for any reason, turn off the anti-fouling unit. Just remember to turn it back on when the job is finished!

Q: Will the ultrasonic anti-fouling cause interference to radio operation on my boat?

A: If you place a portable AM radio on top of the ultrasonic anti-fouling driver unit, you should be able to hear evidence of its operation as a continuously shifting squeal. However, at even small distances away from the driver, such interference should be negligible.

No interference will be caused to marine radio communications or to broadcast FM or TV reception, or to digital TV or DAB+ reception.

Q: Will the ultrasonic anti-fouling unit interfere with the operation of depth sounders or fish finders?

A: No.

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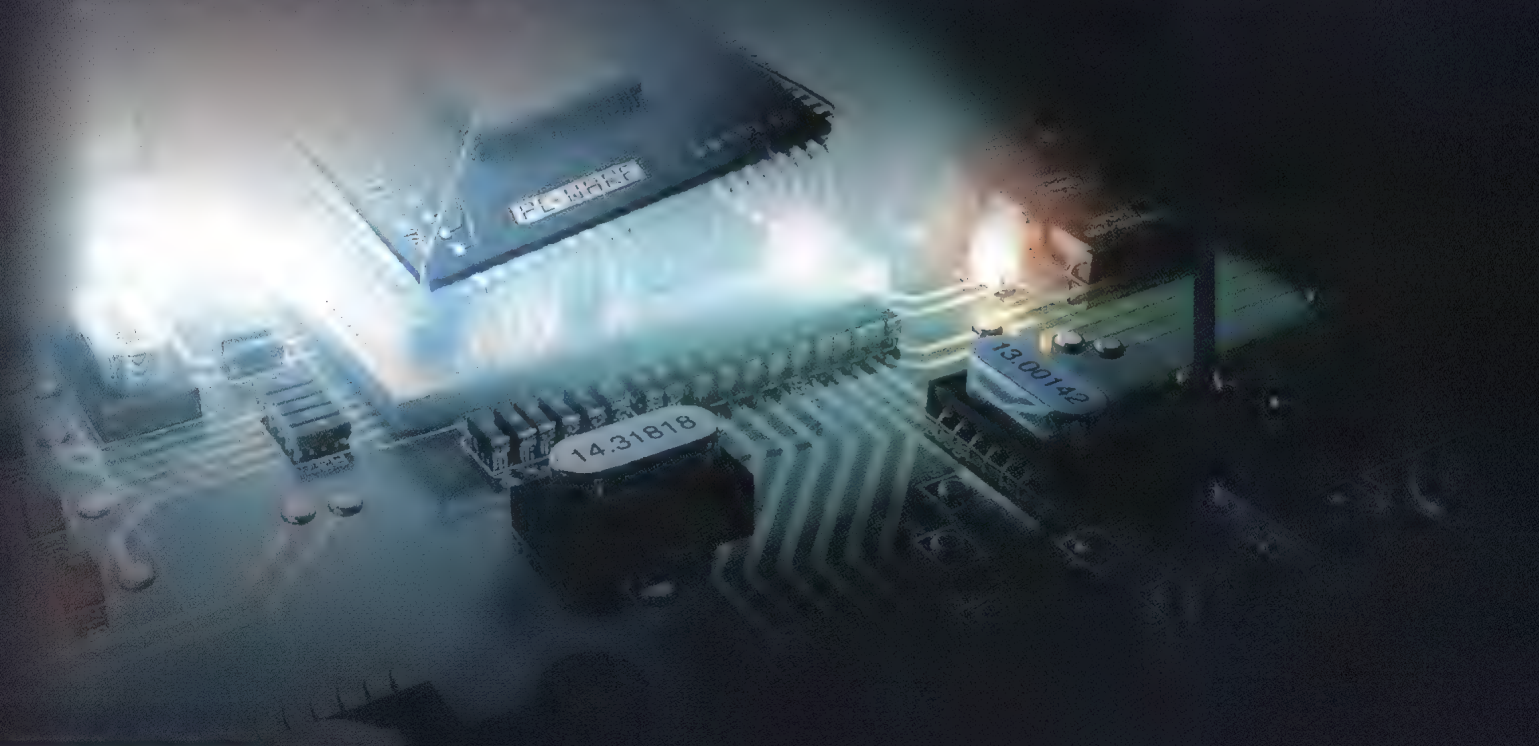

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Getting Started with the Micromite

The Micromite is intended to be used primarily as an "embedded controller". This is the situation where the processor is running a dedicated program to control external circuitry. To help in this role, the Micromite has a number of built-in features such as the ability to balance performance and power consumption, to automatically recover from errors and so on.

Using the CPU command, your program can instantly speed up or slow down the processor and, because the power consumption of the Micromite is related to the processor speed, you can balance speed against power consumption. This is particularly important in battery-powered applications. The command looks like this:

```
CPU <speed in MHz>
```

The speed can be any one of 48, 40, 30, 20, 10 or 5. For example, "CPU 5" will set the speed to 5MHz with a current consumption of about 6mA (for the Micromite alone) while "CPU 48" will set it to 48MHz and it will draw about 30mA.

The default is 40MHz and the speed can be changed at any time so you can speed up for a few lines in a critical part of the program, then drop back to a slower speed to conserve power.

You can further conserve power by sending the Micromite to sleep with the CPU SLEEP command. In this mode, all processing will stop, and the current consumption will drop to about 40µA.

The Micromite can wake up after a specified number of seconds or it can be woken by a change of level on the pin designated as the WAKEUP pin (pin 16 on the 28-pin Micromite).

Note that if you are using the LCD BackPack, the display will continue to consume power (much more than 40µA). If you have software control over the backlight, as in the Plus BackPack or BackPack V2, you should turn it off before executing CPU SLEEP to save power and turn it back on after wake-up.

Saving data

Because the Micromite usually does not have a normal storage system (such as an SD card), it needs to have a facility to save some data so it can be recovered when power is restored. This might be calibration data, user options, the current state, etc.

This can be done with the VAR SAVE command which will save the variables listed on its command line in non-volatile flash memory. For example:

```
VAR SAVE ConfigX, ConfigY
```

On power-up, these variables can be restored with the VAR RESTORE command which adds all the saved variables to the variable table of the running program. Normally, this command is placed near the start of a program so that the variables are ready for immediate use. Using this feature, a typical program would look like this:

```
VAR RESTORE  ' any saved variables are restored
' <rest of the program continues>

' save the variables if they have changed
IF ConfigurationChanged THEN
  VAR SAVE Config1, Config2
```

The VAR RESTORE command at the start of the program will try to restore any (and all) saved variables. If none have been saved, the command will do nothing. Later, the program saves the variables **Config1** or **Config2** if they have been changed and then, when the program is re-started, the VAR RESTORE command will find and automatically restore them.

Interrupts

An interrupt is some event that "interrupts" the main program and causes MMBasic to temporarily execute some other code. Interrupts are a handy way of dealing with an event that can occur at an unpredictable time, for example, when an input connected to a limit switch has gone high.

In your program, you could continuously check to see if the input has changed state but an interrupt makes for a more cleaner and readable

Part 4: by Geoff Graham

If you have been following this tutorial, you should be at the stage where you can now write your own programs for the Micromite. But there are a few more specialised features of the Micromite that we need to cover before you graduate. These include power saving, using touch-sensitive LCD panels and handling button presses, storing data in non-volatile memory, interrupt routines and other embedded controller features.

program (and possibly a faster response to external events). Here is a practical example:

```
SETPIN 5, INTH, MyIntSub
DO
  ' <main program>
LOOP

SUB MyIntSub
  PRINT "Input has gone high"
END SUB
```

The program starts by configuring pin 5 as an interrupt source that will trigger an interrupt when the voltage on the pin goes high (ie, INTH). You can also trigger an interrupt when the voltage goes low (INTL) or when it changes both from low to high or high to low (INTB). The last parameter is the name of the subroutine to execute when the interrupt occurs – this is just an ordinary subroutine.

When an interrupt occurs, MMBasic will temporarily stop running the main program and execute the code in the interrupt subroutine. Then, when the execution of the subroutine has finished, MMBasic will return to executing the main program at the exact point where it was originally interrupted. The main program will carry on as normal.

In the above example, the subroutine would just display a message on the console but you can do anything you wish. For example, you could signal an alarm, reverse the direction of a motor, etc. You can set an interrupt on any I/O pin and you can have up to ten I/O pins simultaneously operating as interrupts, each with its own interrupt subroutine or, if you wish, sharing one or more subroutines.

If two interrupts occur simultaneously, MMBasic will execute the subroutine associated with the interrupt that was defined first, then when it has finished (and if the next interrupt condition still exists) it will execute the next interrupt subroutine, and so on.

While MMBasic is executing the interrupt subroutine, all other interrupts are ignored. This means that if your interrupt code takes too long to execute there is a chance that another interrupt (such as a button press) might arise and vanish while your first interrupt subroutine is still executing. This would cause the new interrupt to be missed; for this reason, interrupt subroutines should be as short as possible.

Many other parts of MMBasic can also generate interrupts. For example, you can specify an interrupt that repeats with a specified number of milliseconds between each interrupt (the tick timer); or you can have an interrupt when an infrared remote control signal is received or when a certain number of bytes has been received on a serial interface.

Normally, MMBasic will respond to a single interrupt within 100µs so you can use interrupts to catch reasonably brief events. For example, ignition pulses in a petrol engine.

Keeping time

In the Micromite, there are many ways that a program can track the time including an internal clock/calendar, a millisecond timer, timed interrupts and the PAUSE command.

The current date and time can be accessed using the special identifiers DATE$ and TIME$ which act like pre-defined variables. These are reset to midnight on the 1st January 2000 at power-up so you need to set the current date and time before you can use them.

This is done by assigning the current date/time (as strings) to these variables. For example, the following will set the Micromite's clock to 4:25PM on May 7th:

```
DATE$ = "7/03/2017"
TIME$ = "16:25"
```

You can also use the RTC command to automatically set the correct time from an external Real Time Clock (RTC) on power-up and then the Micromite's internal clock will always be correct.

Both DATE$ and TIME$ return their value as a string which you can then pull apart using specific string

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functions (or just use it as a string). As an example, if you entered this at the command prompt:

```
PRINT DATE$, TIME$
```

You could expect to see something like this:

```
7/08/2017 16:25:51
```

TIMER is another special variable which returns the number of milliseconds since being reset to zero (it is also reset when the Micromite is powered up). You can use it to measure the time difference between two events as shown in the following example:

```
TIMER = 0
' <timed code>
PRINT TIMER "ms"
```

Sometimes, after sending a control signal to a device, you might be required to wait for a defined number of milliseconds before you can send the next control signal.

The PAUSE command is perfect for this type of job and we have used it a number of times in past instalments of this tutorial – it will simply pause the execution of the program for a certain number of milliseconds.

MMBasic also allows you to set up to four "tick" timers. Each acts like the tick of a clock and on each tick, MMBasic will execute an interrupt subroutine specified in the command. The tick times are specified in milliseconds and can range from a few milliseconds to many days.

For example, the following code fragment will print the current time and the voltage on pin 5 every second. This process will run independently of the main program which could be doing something completely unrelated.

```
SETPIN 5, AIN
SETTICK 1000, TickInt
DO
  ' <main processing loop>
LOOP

SUB TickInt ' tick interrupt
  PRINT TIME$, PIN(5)
END SUB
```

The second line sets up the "tick" interrupt, the first parameter of SETTICK is the period of the interrupt (1000ms) and the second is the interrupt subroutine which will be executed on every "tick". Every second (ie, 1000ms), the main processing loop will be interrupted and the subroutine TickInt will be executed.

Watchdog timer

When the Micromite is running as an embedded processor, it will generally not have anything connected to the console and it will automatically start running its program when the OPTION AUTORUN ON command has been used.

This is fine, however, there is always the possibility that a fault in the program could cause MMBasic to generate an error and return to the command prompt. Another possibility is that the BASIC program could get itself stuck in an endless loop for some reason.

In either case, the effect to the user of the device would be the same; the Micromite would stop doing its programmed job until the power was cycled.

To guard against this, the watchdog timer can be used. This is a timer that counts down towards zero and when it reaches zero, the processor is automatically restarted (the same as when power was first applied), even if MMBasic was sitting at the command prompt.

The WATCHDOG command specifies how many milliseconds are allowed before the reset. For example, the following will set the watchdog timer to 200 milliseconds:

```
WATCHDOG 200
```

Normally, this command will be placed in strategic locations in the program to keep resetting the timer and therefore preventing it from counting down to zero. Then, if a fault occurs, the timer will not be reset, it will reach zero and the program will be restarted (assuming that AUTORUN is set).

To give a practical example, the following program will display the temperature in the centre of an attached LCD display once a second (the TEMP() function returns the temperature from a DS18B20 temperature sensor):

```
DO
  TEXT 160, 120, STR$(TEMPR(4)),
     CM, 1, 2
  PAUSE 1000
LOOP
```

There is very little to go wrong with such a simple program but just suppose that the memory of the Micromite could be hit by a stray cosmic

ray that upset the program causing it to halt with some error. To protect against this you can add the WATCHDOG command as follows:

```
DO
 WATCHDOG 2000
 TEXT 160, 120, STR$(TEMPR(4)),
    CM, 1, 2
 PAUSE 1000
LOOP
```

Every time through the loop, the WATCHDOG command would reset the watchdog timer to two seconds, then the rest of the loop would take a bit over a second to complete before repeating so the watchdog timer will never get the opportunity to reach zero.

But, if the stray cosmic ray did hit and stopped the program, the watchdog timer would continue counting down until it hit zero – at which point the Micromite would be automatically restarted, the program would recommence displaying the temperature and more importantly, the user would only see a momentary glitch.

Handling touch

As well as driving an LCD panel to display graphics and text, the Micromite can respond to touch on the display's screen.

Touch-sensitive panels have a transparent resistive membrane over the LCD screen and when this is touched, the resistance of the membrane changes and the controller on the panel will send a signal (the IRQ signal) to the Micromite, to indicate this event.

The controller will also calculate the position of the touch and MMBasic queries the controller to get this information.

Within your program, it is easy to get the touch position; the MMBasic function calls TOUCH(X) and TOUCH(Y) report the current touch coordinates in pixels. Note that the X and Y used in the touch function are keywords, not variables. If the screen is not being touched, both TOUCH(X) and TOUCH(Y) will return negative one (-1).

As a simple example, the following program will display the coordinates of the current touch location on the console. Because the program runs in a tight loop, the readings will quickly scroll off the top of the terminal emulator's screen but as you touch the screen you can see the precise location:

```
DO
 PRINT TOUCH(X),TOUCH(Y)
LOOP
```

Screenshot 1 provides an example of this program at the instance that the screen was touched. You can see how the TOUCH() function was returning -1 until a touch was detected then it returned the coordinates of the touch.

Adding touch input can make a big difference to a project. It can be used to eliminate inefficient knobs and switches and it allows the designer to implement many more configuration options than would have previously been practical.

The touch system can be very simple (eg, touch anywhere on the screen to proceed) or it could be complex with the screen covered in checkboxes and buttons.

The most common requirement is to display one or more buttons on the screen which act like real buttons, ie, when touched the image of the button changes to show that it is selected and when released it returns to its previous appearance. In this final section of our tutorial, we will describe one way of implementing this feature. This example also serves to illustrate some of the more advanced aspects of Micromite programming.

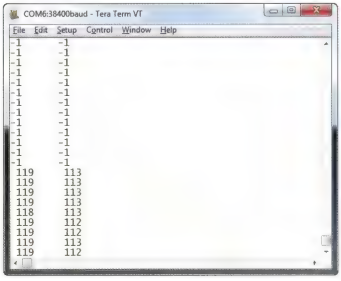
Drawing a button

To start, we need a subroutine to draw a button. The following will draw a button with rounded corners and some text positioned in the centre:

```
SUB Button x, y, txt$, fc%
 LOCAL w = MM.FONTWIDTH *
    (LEN(txt$) + 1)
 LOCAL h = MM.FONTHEIGHT * 2
 RBOX x, y, w, h, , fc%
 TEXT x + w / 2, y + h / 2, txt$, CM,
    , , fc%
END SUB
```

The arguments **x** and **y** are the coordinates of the top-left corner of the button, **txt$** is the text to display in the centre of the button and **fc** is the colour to use for the button.

Within the subroutine, we first calculate the width and height of the required box based on the text to be used as the caption. MM.FONTWIDTH and MM.FONTHEIGHT are read-only



Screenshot 1 (left): this screen capture provides an example of the simple touch demonstration program caught at the instance that the screen was touched. You can see how the TOUCH() function was returning -1 until a touch was detected then it returned the coordinates of the touch.

Screenshot 2 (right): this is what the simple button looks like. The subroutine calculated the dimensions of the box to fit around its caption then, using these dimensions, drew a rounded box and centrally positioned the text inside the box.

variables that are automatically set by MMBasic to the dimensions of the current font and LEN() is a function that returns the length of a string in characters. Note that we are both declaring w and h as local variables and setting their value in the one statement. Also, note that we add to the text's dimensions so that the surrounding box has room for the text.

Using these dimensions, we then draw a rounded box and centrally position the text inside the box. Voilà! We have created a button.

As an example of using the above subroutine, having already defined it, the following will draw a cyan button:

```
FONT #1, 2
CLS
Button 100, 100, "Hello", RGB(cyan)
```

The default font (font #1) is rather small so we use the FONT command to set the default to double size. Screenshot 2 shows what the result looks like.

Detecting touch

It would be useful if we could also tell if this button has been touched. To do this, we can modify the subroutine to check if the current touch coordinates are within the bounds of the button. We also need to convert the subroutine into a function so that it can return a value indicating that the button is indeed being touched. So our new function looks like this:

```
FUNCTION Button(x, y, txt$, fc%)
  LOCAL w = MM.FONTWIDTH *
    (LEN(txt$) + 1)
  LOCAL h = MM.FONTHEIGHT * 2
  LOCAL tx = TOUCH(X)
  LOCAL ty = TOUCH(Y)
  IF tx >= x AND tx <= x + w AND
    ty >= y AND ty <= y + h THEN
    Button = 1
  RBOX x, y, w, h, , fc%
  TEXT x + w / 2, y + h / 2, txt$, CM,
    , , fc%
END FUNCTION
```

This is similar to the previous subroutine in that it first calculates the width and height of the box and draws the button. It also gets the X and Y coordinates of the current touch point and saves them in the local variables tx and ty. We do this because it makes the following IF statement less complex and easier to understand.

The IF statement then checks if the current touch coordinates are within the box and sets the value of the function to one (ie, true) if it is. Note that we do not bother setting the value of the function to zero if the touch is outside the box because this is the default value returned by a function.

Also note that if the user is not touching the screen, the function will still return false because the values returned for the X and Y touch values will be -1, which are outside of the button's area. This function can then be used to easily check if the button has been touched. For example:

```
FONT #1, 2
CLS
DO
  IF Button(100, 100, "Hello",
    RGB(cyan)) THEN PRINT
    "Button touched"
LOOP
```

Note that this program will continuously redraw the button on the screen; this is not a problem because the redraw is very fast and, as the image of the button is not changing, the user will not see any flicker or change in the image.

However, it is useful to give the user an indication that the button is indeed touched and one good way to do this is to display the button in reverse video. This is easy to do, as shown in this further improved version of the Button function:

```
FUNCTION Button(x, y, txt$, fc%)
  LOCAL w = MM.FONTWIDTH *
    (LEN(txt$) + 1)
  LOCAL h = MM.FONTHEIGHT * 2
  LOCAL tx = TOUCH(X)
  LOCAL ty = TOUCH(Y)
  IF tx >= x AND tx <= x + w AND
    ty >= y AND ty <= y + h THEN
    Button = 1
    RBOX x, y, w, h, , fc%, fc%
    TEXT x + w / 2, y + h / 2, txt$,
      CM, , , RGB(black), fc%
  ELSE
    RBOX x, y, w, h, , fc%,
      RGB(black)
    TEXT x + w / 2, y + h / 2, txt$,
      CM, , , fc%
  ENDIF
END FUNCTION
```

We are now drawing the button with the foreground and background colours reversed if touch is detected,

```
FONT #1, 2
CLS
SETPIN 4, DOUT
SETPIN 15, INTB, BtnInt

BtnInt

DO
  ' <program code>
LOOP

SUB BtnInt
  IF Button(115, 50, "START", RGB(red)) THEN PIN(4) = 1
  IF Button(122, 150, "STOP", RGB(green)) THEN PIN(4) = 0
END SUB

FUNCTION Button(x, y, txt$, fc%)
  LOCAL w = MM.FONTWIDTH * (LEN(txt$) + 1)
  LOCAL h = MM.FONTHEIGHT * 2
  LOCAL tx = TOUCH(X)
  LOCAL ty = TOUCH(Y)
  IF tx >= x AND tx <= x + w AND ty >= y AND ty <= y + h THEN
    Button = 1
    RBOX x, y, w, h, , fc%, fc%
    TEXT x + w / 2, y + h / 2, txt$, CM, , , RGB(black), fc%
  ELSE
    RBOX x, y, w, h, , fc%, RGB(black)
    TEXT x + w / 2, y + h / 2, txt$, CM, , , fc%
  ENDIF
END FUNCTION
```

Handy Tip

CTRL-C can get you out of all sorts of difficult situations so remember it because you will find useful at some time in the future.

Fig.1: this program can be used to draw buttons on the LCD screen and also detect if either has been pressed and highlight it, as shown in Screenshots 3-5.

otherwise, the button is drawn normally. If you use this new version in the continuous loop example given above, you will see that the effect of touching the button is obvious to the user.

Sharp-eyed readers will notice that we are now filling the rounded box of our button with a colour (either the colour of the button or black) and because we do that, the button now appears to flicker as it is redrawn quickly. This will not be a problem because in the next section we will only redraw the button on a touch (not continuously) so the flicker will be hardly noticeable.

Touch interrupt handling

The above method of detecting touch works well but a program usually cannot just sit there spinning around waiting for a button to be touched. It will have other duties to attend to, like getting data from a sensor and reacting to it.

The other factor is that you, as the programmer, cannot predict when the user is going to touch the button. From our earlier discussion on interrupts, you might have already guessed by now that this is a perfect job for an interrupt as these are intended for situations where you need to respond to unpredictable events.

What we can do is set up an interrupt on the touch IRQ signal input (generated by the LCD panel when it is touched). If you recall our earlier articles, this signal will go low when the screen is touched and then revert to high when it is lifted.

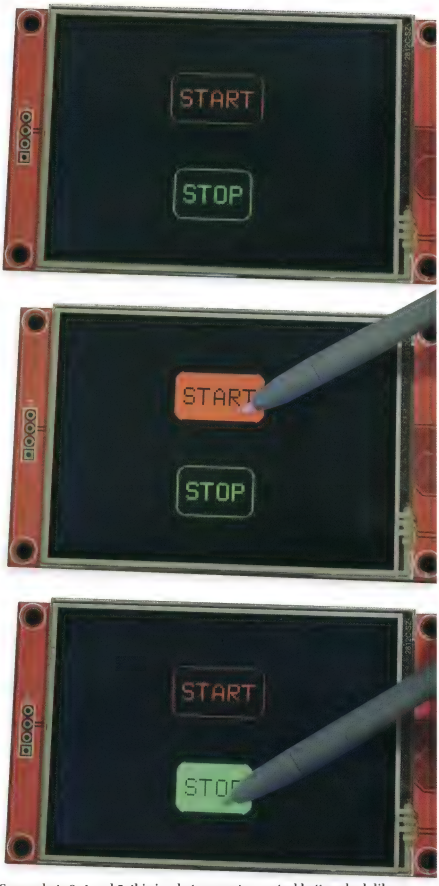
The I/O pin used for this signal was defined in the OPTION LCDPANEL command when you first configured the Micromite to work with the panel. On the Micromite LCD BackPack (V1 and V2), this is pin 15 and we will use this in our example.

Because we want to know when the touch is applied or removed, we set the interrupt to work on both high-to-low and low-to-high transitions as follows (BtnInt is the subroutine to call on the interrupt):

```
SETPIN 15, INTB, BtnInt
```

Now, say that we want to control a motor with two buttons on the screen; the first should be labelled START and coloured red and the second is STOP and is coloured green.

When the user touches START, the program should set pin 4 high (presumably this is driving a relay



Screenshots 3, 4 and 5: this is what our motor control buttons look like on the LCD screen. The first shows both buttons as they initially appear while the next two screen captures show the result of touching the start button and the stop button.

controlling power to the motor) and when the user touches STOP, that pin should be set to low again.

Fig.1 contains the full program, including the Button function. You can copy or type it into a Micromite (or download it from the SILICON CHIP website) and with a suitable display it will run "as is". It uses an interrupt to detect when the user has touched a button and calls the function Button to handle the buttons:

This might look a little daunting so we will go through the new program code line by line. First, we set the font, then CLS is used to clear the screen and pin 4 is configured as an output (this is controlling our motor).

Next, the SETPIN command configures an interrupt on the touch IRQ signal (pin 15). INTB specifies that the interrupt will occur on either transition of this signal and BtnInt is the subroutine to call when that transition occurs.

We then call the interrupt subroutine itself. This is perfectly legitimate as an interrupt subroutine is just a normal subroutine. The reason for doing this is to draw the buttons on the screen initially. After this, the program enters an endless loop where it could be doing things like monitoring input signals and sensors and reacting accordingly.

The interrupt subroutine (BtnInt) is quite simple. It first checks if the START button has been pressed and if so will set the motor (pin 4) to run. Then it checks the STOP button, and if touched, stops the motor.

When we first called this subroutine (just after the clear screen command), there was presumably no touch on the screen so this run through would simply draw the buttons in their normal states (remember that the Button function draws the button as well as checking if it is touched).

Now, if the user touches the START button, the interrupt will be triggered, the Button function will detect that the touch is within the button and it will redraw the button in reverse video. The function will also return true to the IF statement in the BtnInt subroutine, causing pin 4 to be set high and run the motor.

When the user removes the touch, the interrupt subroutine will be called a second time and because no button is touched, the Button function will redraw all buttons in their normal state. Similarly, when the user touches the STOP button, it will be displayed in reverse video and pin 4 will be set low to stop the motor. That is it! There is nothing more that you need to do.

Screenshot 3 shows both buttons as they initially appear while Screenshots 4 and 5 show the result of touching the START button and the STOP button respectively.

You can extend this to as many buttons as you want. For example, you could draw a numeric keypad on the screen so that the user could enter a number. You can also write a different subroutine to draw and monitor a checkbox (you could call it CheckBox), or radio buttons (similar to checkboxes but where only one can be selected at a time), or whatever.

You could also switch between different screens full of different objects by clearing the screen (using CLS) then redefining the touch interrupt to point to a different subroutine which implements the new set of objects.

Note that the Micromite Plus uses a different method of defining a touch interrupt and it incorporates commands to generate and automatically manage screen objects like buttons for you. So the Micromite Plus is much easier to work with and the above code is not necessary if you are using this advanced version of the Micromite.

Other Features

In this tutorial series, we have taken you from the simple features of the Micromite such as setting an output high or low, through programming in MMBasic including expressions, subroutines and functions and on to complex features like displaying graphics on an LCD screen and responding to touch.

However, the Micromite incorporates many more advanced features that are simply too complex to cover in a tutorial like this. The Micromite User Manual (which can be downloaded from the SILICON CHIP website) goes into the detail of how to use these features but in summary, they are:

- The ability to interface to common external sensors for temperature, humidity and distance plus the ability to control mechanical servos and devices that need an analog signal (the PWM command).
- The Micromite can receive and send infrared remote control signals enabling you to add remote control to your creation using a common IR remote control.
- Support for an extensive range of communications protocols which will allow you to connect to and communicate with test equipment, WiFi modules, GPS receivers and a wide range of sensors for anything from acceleration through to atmospheric pollution.
- Graphical controls on the Micromite Plus which include on-screen buttons, switches, checkboxes, radio buttons and more. Each of these can be defined with a single command and from then on MMBasic will manage the object including animating it when the user touches it.
- The ability to customise MMBasic by adding your own commands, functions and fonts to the language (the DEFINEFONT and LIBRARY commands).
- The ability to add to MMBasic commands and functions written in the C programming language or MIPS assembler. These allow you to exploit the full speed and features of the PIC32 processor while still using the easy to program BASIC language for the rest of your program. SC

Information and help on the Micromite

The Micromite is a fully functional computer with a multitude of facilities and the Micromite User Manual which describes it adds up to almost 100 pages. This manual is the ultimate reference for the Micromite and covers everything from the I/O pins through to functions that you might only need in specialised circumstances.

It is in PDF format and available for free download from the SILICON CHIP website (at www.siliconchip.com.au/Shop/6/2907) and the author's website (http://geoffg.net/micromite.html). New versions of the MMBasic firmware and programming examples are also uploaded to the author's website.

A good place to find help is the Back Shed forum (www.thebackshed.com/forum/forum_topics.asp?FID=16) where there are many enthusiastic Maximite and Micromite users who would be only too happy to offer advice.

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KEYSIGHT TECHNOLOGIES

N9917A 18GHz Network/ Spectrum Analyser

Review by
NICHOLAS VINEN

Keysight has a whole family of FieldFox instruments which can be optioned up for bandwidths from 4GHz up to 50GHz+. The model we are reviewing is a combination 18GHz Microwave Network/Spectrum Analyser.

If only because the Keysight FieldFox N9917A has such a huge range of features and functions, we imagine that even an experienced RF engineer would have a steep learning curve to become fully familiar with this instrument.

But when they do, they'll find it a very capable instrument indeed!

Its main functions (depending on the installed options), are as follows:

1. Spectrum analyser
2. Real Time Spectrum Analyser (RTSA)
3. Vector Network Analyser (VNA)
4. Vector voltmeter
5. Time Domain Reflectometry (TDR)
6. Extended Range Transmission Analysis
7. Interference analysis
8. Cable and Antenna Analyser (CAT)

A short description of each of those functions can be seen in a separate panel in this article.

For such a potent instrument, the Keysight N9917A is not particularly large or impressive in appearance. It fact, it is quite unprepossessing. At first sight, it looks like a largish hand-held scope with many buttons, all with a charcoal finish.

It can be used as a bench-top instrument, thanks to a stand which swings out from the back. It's 183mm wide, 295mm tall and 70mm deep and it is fairly heavy at 3kg, no doubt mainly due to its battery.

The FieldFox makes a fine spectrum analyser, however its real strengths appear to be in the area of cable, antenna and amplifier testing and in fault-finding.

It comes in almost bewildering range of models with different capabilities and bandwidths but even once you have chosen your preferred combination, you will still need to specify from an exhaustive list of options, to get a unit that does exactly what you want.

See http://literature.cdn.keysight.com/litweb/pdf/5990-9836EN.pdf

If you purchase a FieldFox Spectrum Analyser then the Spectrum Analysis and signal generator functions are included. If you purchase the Network Analyser version then

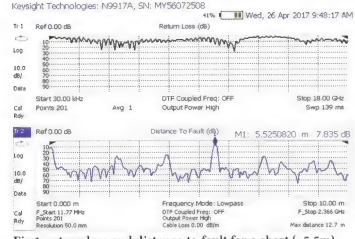


Fig.1: return loss and distance-to-fault for a short (~5.5m) section of cable, open-circuit at the far end, from 30kHz up to 18GHz.

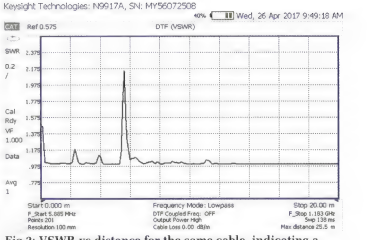


Fig.2: VSWR vs distance for the same cable, indicating a spike in reflection power at the distance of the open-circuit fault.

the VNA Transmission and Reflection functions, including DTF/RL/VSWR measurements are available. Combined SA/VNA units come with the Cable and Antenna Analyser (CAT) function as standard. Everything else is an option.

The other available options for the VNA-capable versions include: time domain VNA, QuickCal calibration, 2-port VNA S-parameter analysis, 1-port mixed-mode S-parameters and TDR.

Available options for the Spectrum Analyser version include: tracking generator, ERTA, pre-amplifier, interference analyser/spectrogram, channel scanner, RTSA and analog (AM/FM) demodulation.

All versions of the FieldFox are also available with the following options: USB-based power measurement, USB-based power vs frequency, built-in power meter, pulse measurement with USB power sensor, remote control, GPS receiver and DC-bias variable voltage source.

Our review unit came with all options enabled, giving it pretty much the full range of FieldFox capabilities.

User interface and connectors

Lacking a manual, it only took us about 30 minutes to become familiar with the FieldFox's user interface and figure out how to use most of the functions. Overall, therefore, we would have to say that it is quite easy and intuitive to use, especially if you have prior experience with this sort of instrument.

Below the 165mm diagonal, 640 x 452 pixel LCD screen are six soft buttons, five mode buttons, the power/standby switch, numeric keypad, jogwheel plus five navigation buttons. At the top of the unit are the two main input/output connectors (N-connectors on this unit, as with most of the FieldFox range) plus SMA connectors for the GPS antenna (if the option is fitted) and the reference/trigger input.

Behind small waterproof rubber doors on the left side of the unit are the DC charging port, DC output (for when the bias supply option is fitted), headphone jack (for demodulated audio) plus a small speaker (ditto).

At right, behind latching doors, are two USB host sockets, one mini USB device socket, an SD card slot, Ethernet port plus two SMB RF connectors for the reference/trigger output and IF output.

The display is suitable for use indoors and outdoors, with adjustable brightness and various different colour schemes that you can choose from, which are set up to suit different situations. We tested it indoors and out and didn't have any problems viewing the screen.

Initial switch-on takes about 60 seconds, while shut

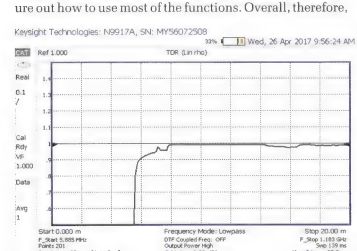


Fig.3: time domain reflectrometry analysis for the same cable; this is another different way of finding the same fault.

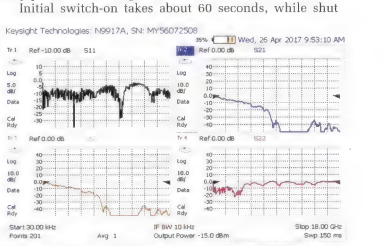


Fig.4: in VNA mode, displaying the real (amplitude) part of four S-parameters plotted against frequency at the same time, for the same cable. The forward and reverse loss plots are almost identical but reflection differs at each end due to different connectors being used.

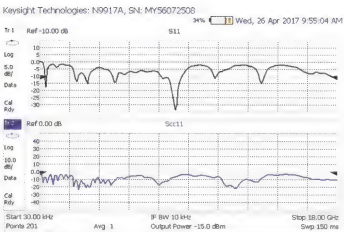


Fig.5: differential and common mode reflection parameters for one end of the same cable as shown in Fig.4, plotted simultaneously and over the same frequency range.

Fig.6: using either the internal power meter option or USB power meter option is easy; select the frequency, bandwidth and optionally radio standard and the received power level is displayed.

down takes around 10 seconds. However, it does have a standby mode which can be initiated in just a couple of seconds and restoring the unit to operation from standby takes just a few seconds. So you would typically only need to boot the unit up once per day and you could leave it in standby between uses.

The first step to setting the unit up after switch-on is to press the Mode button which reveals a choice of ten different modes (on our test unit): CAT / TDR, NA (Network Analyser), SA (Spectrum Analyser), RTSA, VVM, Power Meter (USB), Channel Scanner, Pulse Measurements, ERTA or Power Meter (built in). Selecting one of these loads the appropriate "application" which takes a few seconds.

In each mode, you change the settings either by pressing one of the dedicated buttons below Mode, to change the frequency/distance range, display scale/amplitude, markers (up to six are supported) or access marker tools such as peak searching.

Further settings can also be made by pressing one of the numeric keypad buttons, most of which are labelled with additional functions.

These are: Measurements, Bandwidth selection, Sweeping, Measurement Set-up, Calibration, Trace set-up, System settings, Limit lines, Save/Recall, Presets and Run/Hold.

The biggest hurdle to operating the FieldFox is understanding which options are available under each of these menus in each mode. Once you know that, it's pretty easy to figure out how to change the parameters required to achieve your desired results.

Operation and performance

We started out by testing the FieldFox's fault-finding capabilities.

We don't have any really long cables to test it with, especially not with built-in faults, but it was able to accurately identify the distance to open or short circuits on various cables we tested it with.

Fig.1 shows the unit measuring the return loss and DTF of a short coaxial cable, using the screen colours designed for use in direct sunlight.

Its reading of 5.5m was very close to the actual length. Note that we reduced the scale of the reading to make it more clear; the default DTF scale goes up to 100m and longer distances are possible, up to 5km.

Figs.2 & 3 show the unit measuring the same cable in VSWR fault-finding and TDR mode respectively. Both show

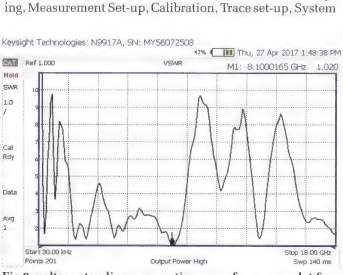


Fig.9: voltage standing wave ratio versus frequency plot for an antenna on the end of a cable. This provides an accurate means of tuning the antenna for a specific frequency.

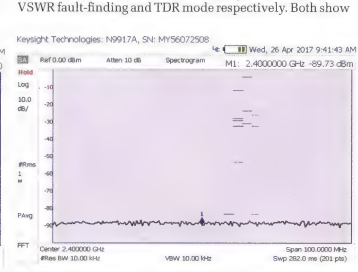


Fig.10: spectrogram of the 100MHz band centred around 2.4GHz, showing WiFi activity. Spectrogram plots are available in both spectrum analyser (SA) and RTSA modes.

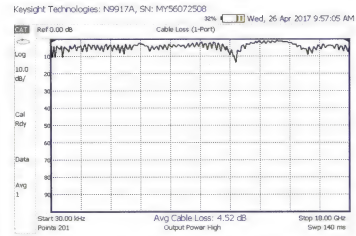


Fig.7: single-ended cable loss analysis plot; we're not convinced that this is an accurate way to measure cable loss but the facility is provided for when you have no other option.

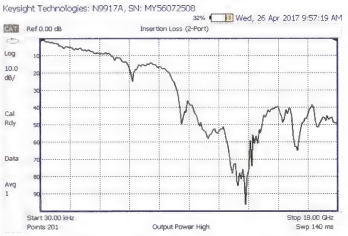


Fig.8: insertion loss for the same cable, measured with both ends connected. This tells a very different story and shows the cable and connectors are really only suitable for use up to a couple of Gigahertz.

the same fault at around 5.5m, in a different manner.

Fig.4 shows the flexibility of the unit when operating as a VNA (Vector Network Analyser). We have connected a series of cables and connectors between its terminals and it is displaying all four of the main S-parameters across the 18GHz frequency span. S12 and S21 show the cable loss in either direction while S11 and S22 show the amplitude of reflections at both ends across the whole frequency range.

Analysing a cable isn't a terribly interesting test case, but this does show the flexibility of the unit in setting up different displays. You can show one, two, three or four parameters on screen at one time and you can choose to display any parameters in any part of the screen, with different scales if necessary.

The VNA mode could be used to test, measure and optimise individual sections of an RF circuit but to perform those tasks you would not only need the FieldFox unit but also suitable probes/cables and calibration hardware to allow the FieldFox to eliminate the characteristics of the probes and cables from its readings.

The FieldFox supports several different means of calibration, which is extremely important to get accurate results, especially at higher frequencies.

While the graphical representation of the S-parameters shown in Fig.4 can be used for fault-finding, in a lab setting where the FieldFox is being used to characterise RF circuitry or hardware, you would be more likely to off-load the parameters (via USB, Ethernet or SD card) onto a PC for further analysis.

We found this very easy to do, using the Save/Recall menu. You can export the data in multiple formats, including CSV.

Fig.5 shows the unit being used in "mixed mode", this time showing two traces on the screen. At the top is the same S11 input reflection parameter visible in Fig.3, this time a bit clearer.

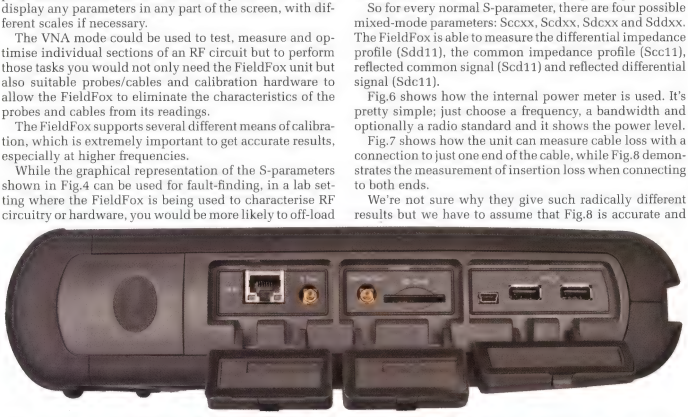
Below it is shown the plot of Scc11, the cable's common impedance profile. "C" here stands for "common mode" while "D" would refer to differential signalling.

So for every normal S-parameter, there are four possible mixed-mode parameters: Sccxx, Scdxx, Sdcxx and Sddxx. The FieldFox is able to measure the differential impedance profile (Sdd11), the common impedance profile (Scc11), reflected common signal (Scd11) and reflected differential signal (Sdc11).

Fig.6 shows how the internal power meter is used. It's pretty simple; just choose a frequency, a bandwidth and optionally a radio standard and it shows the power level.

Fig.7 shows how the unit can measure cable loss with a connection to just one end of the cable, while Fig.8 demonstrates the measurement of insertion loss when connecting to both ends.

We're not sure why they give such radically different results but we have to assume that Fig.8 is accurate and



The right side of the unit with the three locking doors open. The LAN and USB device ports can used for remote control and offloading captured data. The SD card and USB device ports provide an alternative means for copying data from the analyser to a PC.

Fig.7 shows that single-port cable loss measurements tend to underestimate losses.

One thing we quickly learned in operating the FieldFox is that generic BNC/BNC type cables tend to have very high insertion loss, especially above a few GHz; even quite short ones. And of course, every adaptor and connector along the way degrades the signal.

If you need to transmit a high frequency signal along a cable without significant loss, the FieldFox is an invaluable tool for evaluating whether the cable you're using is up to the task.

Fig.9 shows the measurement of the VSWR of a Diamond RH799 70-1000MHz stub antenna connected to the end of a BNC cable. As you can see from the marker information at upper right, despite being designed to operate below 1GHz, the minimum VSWR is 1.02 at 8.1GHz, indicating that this could be the most efficient frequency for the cable/antenna combination (ie, the lowest reflected power).

Other troughs indicating high efficiency are at 4.58GHz (VSWR 1.5), 2.9GHz (1.4), 2.25GHz (1.375) and 365MHz (1.2). No doubt the cable plays a role in these figures.

Fig.10 shows a spectrogram of the 100MHz band centred around 2.4GHz, received using that same antenna. The horizontal bars indicate sporadic activity at that frequency. You can see WiFi devices transmitting on around four different bands between about 2.41 and 2.42GHz.

At the time of the capture, no devices were transmitting, as indicated by the essentially flat black line. We used the regular spectrum analyser for this display since the RTSA has a much more limited frequency span (up to only 10MHz).

Note that these signals show up quite clearly, despite the antenna being designed for sub-1GHz frequencies. It was able to pick up AM and FM radio just fine, too, and the FieldFox can even tune into and listen to them (in case you need to find out who's interfering with your signal...).

Conclusion

It's difficult to provide a full evaluation of the N9917A FieldFox analyser for a number of reasons.

Firstly, there aren't many other devices out there with such a wide range of capabilities.

Secondly, we are not RF experts and so many of the capabilities of the device are new to us, and we have a limited familiarity with the potential applications of this technology. Also, given the large number of features, we don't really have the space to fully do it justice.

However, a few things have become clear from our time with the FieldFox. Firstly, if you load it up with options, it's clearly a very powerful instrument and would be in-

Here is a short summary of the various main functions that are available i

Spectrum analyser

A spectrum analyser analyses an AC signal and produces a plot, or a set of coefficients, representing the magnitude and phase of all the various different frequency sinewave components of that signal, at a particular moment in time and over a specified range of frequencies.

For example, you can connect an antenna to a spectrum analyser to determine the carrier frequency and bandwidth usage of radio transmitters in the area.

Each signal picked up will show up as spikes on the spectrum analyser plot, centred around the carrier frequency, with shape depending on the bandwidth. Analog transmissions normally have a bell-curve (Gaussian) shape while digital radios (eg, WiFi transmitters) tend to produce a more square shape.

A spectrum analyser can also be used with a "tracking generator", as a basic form of network analyser. The output of the tracking generator is fed into a network and the spectrum analyser analyses the output.

The tracking generator's frequency sweeps over the same frequency range as the spectrum analyser is capturing. The result is akin to a frequency response plot.

Real Time Spectrum Analyser (RTSA)

Spectrum analysers have various parameters that the user can adjust which control the trade-off between dynamic range, bandwidth and analysis time (eg, "resolution bandwidth" [RBW]).

The greater the required dynamic range and the finer the bandwidth, the longer the spectrum analyser needs to capture and analyse the data.

As a result, short signal bursts may be missed or "smeared". This is the inevitable interaction between the frequency domain and time domain; ie, AC signals are only meaningful over a finite period of time.

An RTSA is a spectrum analyser that provides a compromise more geared towards capturing fast-changing signals. It not only provides rapid analysis but also analyses time-overlapped data, such that any sporadic signal burst is guaranteed to be picked up. RTSAs can often display the results in a "waterfall" view or spectrogram (see Fig.10), to allow you to visualise all this data.

Vector Network Analyser (VNA)

A VNA is a device which produces a parameter matrix which describe the AC behaviour of an electrical network at a particular frequency.

The FieldFox can operate as a two-port VNA which means it can analyse a network with one single-ended or differential input and one single-ended or differential output. That includes devices like filters, amplifiers, attenuators and transmission lines.

The most common output from a VNA is a set of scattering parameters or S-parameters. In the case of a two-port network, this matrix comprises four complex numbers. They represent the gain and phase of the following aspects of that network: forward voltage gain (S21), reverse voltage gain (S12), input port voltage reflection coefficient (S11) and output port voltage reflection coefficient (S22).

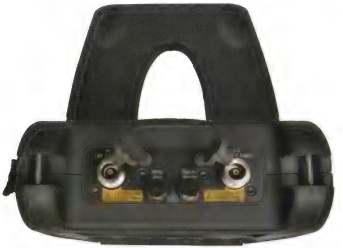
From these four parameters, you can also calculate the following (at least): complex gain, scalar gain, insertion loss, input return loss, output return loss, reverse isolation, reflection coefficient and voltage standing wave ratio (VSWR).

To fully characterise a component or network, the analyser will generate a set of S-parameters over a stepped range of frequencies (see Fig.4).

These measurements can be used for checking the per-

valuable for field work which involves fault-finding, cable and antenna optimisation, measurement of interference and spectrum usage and so on.

Secondly, it's quite a practical and easy-to-use device and once you become familiar with its amazing capabilities, you will find it very satisfying to use.



At the top of the analyser, the input/output N-connectors and SMA sockets for GPS antenna and reference input all have waterproof caps.

Keysight have also apparently put quite a lot of effort into making it easy to calibrate for accurate results, which is absolutely critical for this type of device in a lab environment. Note though that SILICON CHIP does not have the equipment to make calibrated measurements and comment on their accuracy.

Thirdly, the range of options is quite astounding and a single properly-configured FieldFox could easily replace a range of separate RF test instruments. We believe it would be an invaluable tool for an RF field engineer.

If we have *any* criticism, it would probably be the display; while it's quite large and bright, the resolution pales in comparison to today's tablets and portable computers.

Having said that, if you need to examine a signal in detail, you can always off-load the data and that's what most users would need to do for proper analysis anyway.

This is a serious tool and we believe potential customers given a demonstration of its capabilities would be able to quickly determine whether it's the right tool for them.

For more information

Contact Keysight on 1800 629 485 or email tm_ap@keysight.com

e Keysight FieldFox instruments:

formance of antennas, seeing how cabling affects antenna performance, verifying RF amplifier stability, checking the correctness of RF PCB layouts, checking whether connectors are working properly and so on.

They can also be used to characterise passive component networks such as filters.

One important (and yet often overlooked) use for a VNA is to analyse the performance of cables and probes used in test equipment such as high bandwidth oscilloscopes, so that cable/probe loss can be compensated for by the scope, giving much more accurate measurements (See: www.microwavejournal.com/AgilentCableLoss).

Vector voltmeter

According to Wikipedia, a Vector Voltmeter is "a two-channel high-frequency sampling voltmeter that measures phase as well as voltage of two input signals of the same frequency".

This is one of the key components of a Vector Network Analyser but can have other uses, so FieldFox devices with VNA capability also provide you with the vector voltmeter function.

Besides those measurements already available from a VNA, you can also use a vector voltmeter to measure the distortion of radio frequency waves and the complex impedance of mixers, to give two examples.

Time Domain Reflectometry (TDR)

This is a technique for detecting the location of shorts/breaks/faults in a cable by making a connection at only one end. A signal is injected into that end of the cable and the device then "listens" for the reflection. By analysing the delay, phase and amplitude of the reflection, it is possible to get a rough idea of the location and type of fault. See our articles on TDR in the November and December 2014 issues for more information and see Fig.3.

Extended Range Transmission Analysis

This is a system developed by Keysight to measure the gain or loss in a very long cable, where it would be impractical (or impossible) to connect both ends of the cable to the same measurement device. It involves using two FieldFox VNA/SA devices, one at each end of the cable. Essentially, it involves synchronising the two devices in such a way that they are able to operate as if they are one instrument.

Interference analysis

This involves using a spectrum analyser, with a persistence display, to look for transient interfering signals above a certain power threshold, within a given frequency range.

Cable and Antenna Analyser (CAT)

A device able to calculate parameters such as Insertion Loss, Return Loss and VSWR (see Figs.8-9) and also plot them against calculated distance in order to estimate the location (in cabling) of any problem spots (eg, kinks in cables) which result in poor performance of the system as a whole. This is related to but somewhat more complex than TDR and usually involves Frequency Domain Reflectometry (FDR).

A major advantage of using FDR rather than TDR to calculate the Distance To Fault (DTF) in an RF system is that FDR can be performed at the system's normal operating frequency, so the test signal can pass through filters and tuned circuits (as the normal signal would) and it also tests and analyses cables and antennas at their rated frequencies (see Fig.1 & 2). SC

PRODUCT SHOWCASE

New base receiver from Icom raises the bar

With the move towards digital radio technology for two-way communications, the requirements to monitor frequencies becomes more complex. With government organisations moving to advanced technologies such as APCO P25, the role of a traditional analog receiver has narrowed.

The new Icom IC-R8600 Wideband Receiver raises the bar. It uses the experience gained in the development of the IC-7300 (SDR) amateur transceiver, to deliver a receiver covering 0.01-3000MHz through AM, FM, USB, LSB and CW modes.

The IC-R8600 will decode multiple digital protocols, including APCO P25, dPMR, D-Star, NXDN, IDAS and RTTY.

The receiver features a large 4.3" TFT touch screen but can connect to a PC for remote control using the RS-R8600 software. The fast moving, real-time spectrum scope and waterfall functions aid tuning.

The optional matching SP39AD speaker also features an integrated power supply. This is an ideal solution where effective audio output is required.

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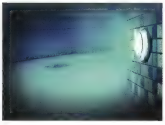
Electrolube solves unusual underwater LED application



Electrolube was recently approached by a company in Australia for assistance with a particularly unusual application. The customer needed protection for an underwater LED lighting unit. The encapsulation resin needed to be light blue for aesthetic purposes and had to be able to withstand water temperatures between 5 to 40°C, as well as being flame retardant.

The customer specifically asked for a sample of a very flexible encapsulation resin that could resist attack from constant immersion in pool water. Critically, this could be salt or fresh water.

The first issue to overcome was the material was sedimenting over time and was increasingly more difficult to reincorporate back into the resin mix; the second was that there was a slight bleed of resin through the gap between the resin and the LED unit. With a bit of lateral thinking, the logical solution was to increase the thixotropic nature of the resin, which would help to slow down the rate of sedimentation to an acceptable level and prevent the resin bleeding through the gap.

Following two weeks' laboratory work, where a number of different options were tested, Electrolube's R&D team produced a material that was still very easy to mix and pour into the unit; in fact the increase in the mix viscosity of modified resin was only slightly higher than the original resin and the colour of UR5097 was altered to the desired colour shade, matching against a RAL standard. This produced a completely bespoke solution that effectively resolved the customer's issues.

The polymer used in the resin is also highly resistant to the transmission of water even at various pressure differences experienced due to the depth of the water.

Contact:
HK Wentworth
Sydney, Melbourne, Brisbane, Perth
Tel: (02) 9938 1566
Web: www.electrolube.com.au

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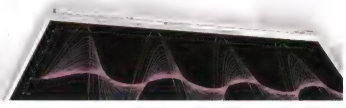

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Creating a 3D Scanner with Raspberry Pi

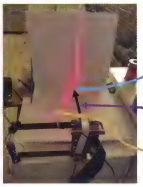
This project by Siddharth of MathWorks lets you build your own 3D scanner which can then be used to recreate the scanned object with a separate 3D printer.

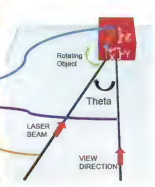
It works by fixing an object to be scanned onto a turntable driven by a stepper motor, then taking two photos of the object; one with a vertical laser line at a fixed angle from the camera and one without.

The difference in the two images (the points where the laser intersects the object) gives one part of the points required to recreate the image in 3D. This process is then repeated for the next 360° in fixed increments (default 0.225°).

The MATLAB program that is run to perform this task is not too complex and relies on some trigonometry among other things.

The point cloud that is created is a series of point values in 3D space that can then be imported into the free open-source software MeshLab (**www.meshlab.net**). The 3D mesh created can then be cleaned and converted with software such as Netfabb for use in a 3D printer.





Shown above is the complete project in action and below is an example point cloud of a torus.

The project requires a few parts such as a Raspberry Pi with camera, line laser diode, stepper motor and driver, along with the parts needed for the frame as listed in the link at the end.

A complete guide can be found at: **http://siliconchip.com.au/l/aact**

Contact:
MathWorks (Australia)
Website: au.mathworks.com

Accelerated 4G Router provides backup for ADSL

The Accelerated 6300-CX router has an embedded, carrier-certified cellular modem that provides Internet connectivity via 4G LTE and 3G cellular wireless data networks. The compact devices, which are designed and developed by a specialist engineering team based in Brisbane, are sold globally by US-based Accelerated Concepts Inc.

The 6300-CX include all modern mobile modes including LTE, 4G, 3G, UMTS, HSPA+, HSPA, EDGE, GPRS and GSM. It can be used for a dedicated internet connection or in fail-over mode to back up an existing ADSL connection. It incorporates firewall, port forwarding, blocking/filtering and NAT/routing functions and supports both IPv4 and IPv6.

The 6300-CX can be placed in a location with the best 4G/3G signal strength and connected to the network via a standard Ethernet cable. It includes a battery for site survey, to identify optimal signal strength placement. It uses two dipole antennas for the best possible performance and supports Power over Ethernet for situations requiring remote power.

Contact:
Accelerated Concepts Pty Ltd
250 Sherwood Rd, Rocklea Qld 4106
Web: www.accelerated.com/products/6300_cx_lte_router/.au

Master Instruments' big move

Master Instruments Pty Ltd (MI), family owned and operated for 75 years, has recently completed a move into their new premises in Milperra, south-western Sydney, kicking off the next exciting phase of business growth.

Having outgrown its spiritual home for the past 60 years in Marrickville, the directors of Master Instruments have invested heavily into finding and acquiring a suitable, and much larger, premises to build on its already growing market share.

The 5,500m^2 building will house the administration and main sales office, battery manufacturing lines and packaging, engineering & tool shop, electronics laboratories, R&D, meter production and two warehouses. *sc*

Contact:
Master Instruments Pty Ltd
13 Sheridan Close Milperra, NSW 2214
Tel: (02) 9519 1200
Web: www.master-instruments.com.au

By Associate Professor Graham Parslow

HMV's 1951 Portable Model B61D

Portable radios became quite popular in the 1950s and 1960s, especially with the arrival of beach culture. And while they were quite expensive, relatively heavy and their battery life could be quite short, their cabinet designs were attractive and they are now very collectible. The HMV B61D portable is a good example.

This restoration project came about after a spousal edict to clean up the storage shed. Well, "clean up" has a variety of interpretations and I discovered a temporarily forgotten pile of HMV portables, hidden by a bank of shelves. Obviously, I needed to attend to these portables as a first priority – the clean-up could wait!

The set that started this collection was a cream model purchased in 2004 from a shop in Kadina, South Australia, for $15. It had a broken speaker grille, no carry handle and a damaged celluloid dial.

That first radio is unremarkable but it brought back the nostalgic pleasure of visiting the country area where I grew up, having not returned for many years.

At the time, I wanted to restore that first HMV portable but it needed a range of salvaged parts. So over the years a number of these HMV portables had been "found" and subsequently added to the "fix it someday pile". Ultimately, I acquired nine HMV portables, all of them broken in some way.

They exhibit a range of defects likely to found on 1950s HMV portables. The most vulnerable item is the celluloid dial. With age, these dials become very brittle and will crack from even the slightest impact.

The celluloid was manufactured flat then bent into shape by pushing it into internal mouldings of the case that retain the top and bottom. This creates stresses that eventually lead to cracking.

In my collection of nine radios, only one had an intact dial and unfortunately that was accidentally broken after its picture was taken. Apart from cracking, the celluloid also yellows and becomes opaque with age.

The next most common problem is damaged or missing cream plastic collars that enclose the ends of the carry strap. Also common is cracking of the case and the backing panel.

Plasticisers were added during manufacture to make the case resistant to cracking, but they lose their efficacy over the years and the plastic becomes brittle.

The most broken case among the nine is testament to a brush-tail possum that got into the shed and knocked the radio to the floor, creating a Humpty-Dumpty scenario. Fortunately plastic-model glue enabled a durable and neat repair of the cabinet.

The radio featured here was chosen to be the first for restoration because it was largely intact. It is also the earliest of the models that span the period 1951 to 1956. During this time, EMI (the manufacturer of HMV-branded sets in Australia) retained the same case while making changes to circuitry and components.

Another good omen was that the original diagram showing the circuit (Fig.1) and component layout (Fig.2) was still in this radio and is reproduced here. It also appears in the 1951 Australian Official Radio Service manual, where extra details have been included. A date stamped on the loudspeaker indicates that the radio is a 1951 model B61D, despite the seller's tag claiming it was a 1954 model 22-1.

Three of the nine sets in my collection have the optional built-in mains adaptor but the model featured here is a dedicated portable. It needs 1.5V to run the valve filaments that are arranged in parallel; mains-powered models use a series connection. Four of the valves are from the One-series (1T4, 1R5 and 1S5) indicating a nominal filament voltage of 1V.

In practice, all of these valves exhibit low emission at only 1V. The exception is the 3V4 output pentode that has a nominal 3V filament but it's arranged with a centre tap so that it can be run as two 1.5V filaments in parallel.

Using a bench power supply for the low tension and sweeping through the range 1 to 2V provides a workable volume control. This emulates the manner in which many radios of the 1920s provided volume control while minimising battery current. Excellent performance came from this radio with the 1.5V battery delivering 250mA to the filaments (0.375W) while the HT current at 90V drew 12mA (1.1W). The maximum audio output is around 250mW which is adequate for most listening.

The front end gets signal from a loop antenna (wound inside the back panel of the cabinet) that can be augmented by adding an aerial to the screw terminal on the back of the case. This was before the days of ferrite rod antennas which are far more efficient at signal pickup. Hence, an external aerial significantly enhances the performance of this set.

It has a 3-gang tuning condenser and the first tuned circuit is an RF amplifier employing a 1T4 pentode valve. This is followed by a conventional superhet circuit, with a 1R5 mixer-converter (frequency changer) followed by a 1T4 functioning as an IF amplifier stage. Its plate drives the second IF transformer and its secondary feeds the 1S5 which combines a single diode and a pentode. The diode serves the dual role of

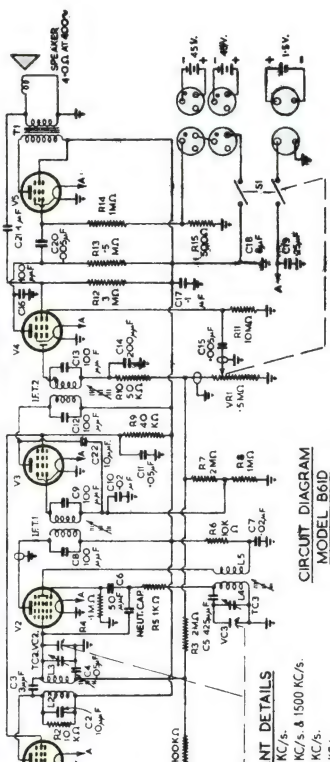


Fig.1: the HMV B61D portable used battery valves with filaments which are run from a 1.5V supply. The 90V HT supply was provided by two 45V batteries connected in series. It is a conventional superhet with a wound loop antenna.

The chassis is mounted upside down in the cabinet and the central area is vacant to provide clear space around the rear of the speaker. The circuit diagram is just visible under the battery pack. The wound loop antenna is on the rear panel of the cabinet.

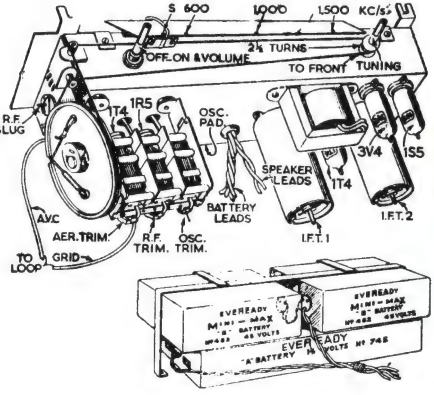
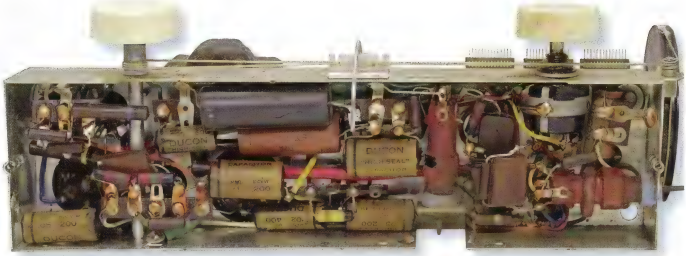


Fig.2: unlike many sets, the dial stringing arrangement for this HMV portable was easy to follow. The battery pack used two 45V batteries for the HT rail and one large 1.5V battery for the filament supply.

Batteries for portable radios were mated with polarised plugs (2 or more pins) to ensure correct connection to the circuit.



The underside of the chassis is in original condition and surprisingly no components needed to be replaced, even though they are all more than 60 years old. It would be more usual to find that many of the capacitors would be leaky or even open-circuit and many the resistors would have gone high in value.

demodulation and producing the AVC (automatic volume control) voltage.

The negative AVC voltage is derived from the junction of R10 and the volume potentiometer VR1 and is applied to decrease amplification in each of the three preceding valves. It is applied to the 1T4 RF amplifier via R3, R1 and C1 and to the 1R5 frequency changer via R3 and C4. Finally, AVC is applied to the 1T4 IF amplifier from the junction of R7 and R8 and filtered with C10.

The demodulated audio signal from the volume control is applied to the grid of the 1S5 pentode section via capacitor C15 which blocks the DC component.

The amplified signal from the plate of the IS5 to the grid of the 3V4 output pentode via C20. This valve gets its negative bias for the grid from the 500Ω resistor which is in series with the negative return for the HT supply.

This is a conventional transformer-coupled Class-A output stage. Negative feedback is applied from the secondary of the transformer to the screen grid of the previous pentode stage. Overall, this is a high quality design for the times.

Interestingly, there is only one electrolytic capacitor in the whole circuit; the 8µF capacitor which bypasses the 90V HT rail.

Chassis layout

The chassis is mounted upside-down at the top of the radio. The flanges on the top cover slide into moulded grooves to make installation and removal easy. The arrangement guides the control knobs to neatly line up with the access slots at the front.

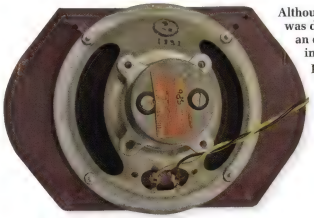
The chassis is held in place by nuts tightening onto screw threads that are embedded in the case. A pair of long-nose pliers and a socket driver are needed to remove and install the nuts in the confined space at the front of the case.

Later models had the model number stamped on the chassis. This one only has the serial number 078112 impressed into the metal so that it aligns with a hole in the back panel to allow reading without taking the back off.

The generous battery compartment at the bottom allows for high capacity batteries that may have lasted for a year or so of typical service. Models with a mains adapter have less battery space and use a different set of batteries. The batteries connect to a wiring loom that has plugs configured so that only correct connections can be made. The sockets in the batteries can be seen in a picture of the Eveready battery.

Sockets are located at the top of the 45V type 482 and at the side of the 1.5V type 745. Eveready was the top selling brand of the time, but another of the HMV portables in my collection had a set of Diamond brand batteries installed.

As seen in the rear view, the loop antenna terminates on a tag strip connected to leads from the chassis via solder joints. This is inconvenient and later models used a plug and socket connection to allow the back to be completely separated. Conveniently,



Although the cabinet was designed to have an elliptical speaker installed, early production examples often used 5-inch round speakers and a Masonite baffle adaptor.

the speaker has clip-on connectors that make disconnection easy.

The case has been designed to take an elliptical speaker but these speakers were uncommon at the time this radio was made in 1951, although they could be found in radios made by specialist manufacturers like Stromberg Carlson. This early model has a Masonite baffle to adapt a 5-inch round speaker to the elliptical space.

HMV models manufactured later in the 1950s were fitted with correctly dimensioned elliptical speakers and these could be expected to provide a better sound level, important when there is only 250mW of power available.

On the positive side, the fitted 5-inch speaker has a substantial field magnet which would no doubt give good acoustic efficiency. Miscellaneous ferrous objects stuck to this magnet tenaciously.

The chassis is quite spartan and components are placed in logical progression from the front end to output. An awkward aspect for bench work is that the dial pointer is under the upright chassis and can easily be bent if not suspended appropriately. Wood blocks at the ends can protect it.

The dial stringing is simple and effective and all of the examples in my collection were intact. A nuisance after getting ever more fragile over 75 years is that the hubs of the cream plastic knobs have a tendency to disintegrate. It is much like the stalk coming out of a mushroom.

Despite considerable care, both knob hubs broke on this radio during removal. Short sections of rubber hose that firmly fitted over the ¼-inch shafts were epoxy glued to the centre of the knobs to restore their function. The lid that is at the top in the assembled radio also anchors the brown backplate for the dial.

This early radio has large capacitors and resistors with the old colour markings found in radios of the 1940s. Later models in this series had smaller components and relatively more space for servicing. Fortunately, this radio worked from the outset so the clutter and over-layering of parts was not a problem.

In fact, it worked first time and sounded good, with excellent selectivity, volume and accuracy of dial calibration. There was no need to touch up the alignment and the usually suspect coupling capacitor to the 3V4 output pentode worked fine, causing no problem with bias to the grid.

This was lucky because it meant that I could keep the original under-chassis look which is characteristic of radios of the 1940s into the early 1950s. After all, some people spend hours putting polyester capacitors in the old shells to keep the original look – which they then hide in the assembled radio.

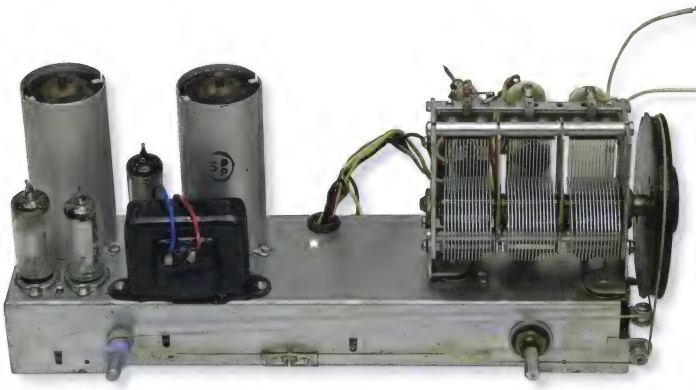
Two coils have provision for external adjustment when the lid is installed. They are the RF coupling coil under the dial-cord drum and the local oscillator located two thirds along the chassis.

Fixing the dial

The dial from this radio had a crack that was very apparent when the celluloid was under tension in the radio.

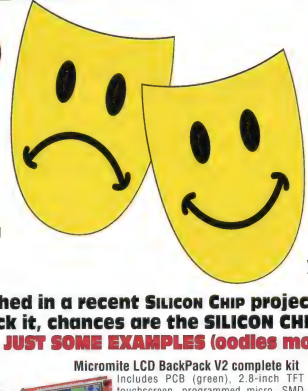
My solution was to photo scan the dial in black and white, edit out the blemishes, and then colour back to yellow. The artwork was then printed on an overhead projector transparency. In this case it was a batch job to create dials for all the other HMV portables in the collection.

Satisfyingly, Little Nipper could happily resume listening to His Master's Voice on this radio. SC



The topside view of the chassis shows its very clean condition. Note the simple dial stringing arrangement. Virtually all of the restoration work involved the cabinet and the making of a replacement for the celluloid dial.

SAD



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CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.

Low power switched capacitor DC/DC Converter for rechargeable batteries

Many devices these days run on Lithium-ion cells because they are cheap, convenient and have an excellent lifespan and power density. But the variable output voltage, typically around 4.2V when fully charged and 3.3V when flat, can be a problem if you want to power ICs that need 5V; you need some way to boost the voltage.

This circuit is a simple switched-capacitor design based on a low-power CMOS 555 timer IC, which has a quiescent current of around 0.1mA. It provides a positive output that can be fed to a low-dropout 5V regulator for a steady 5V supply, able to provide up to about 25mA even when the Li-ion cell is nearly flat. It also provides a negative output, capable of about 10mA, that can be used to power an op amp to extend its voltage range all the way down to 0V and perhaps beyond.

It works as follows. IC1 is a low-power CMOS 555 timer and it is configured for operation at around 20kHz, set by the two 10kΩ resistors and the 3.3nF capacitor connected to pins 2, 6 and 7. Schottky diode D5 between pins 6 and 7 evens out the charge and discharge time for the 3.3nF capacitor, so the output duty cycle is close to 50%.

At the beginning of each cycle, the 3.3nF capacitor has about 1.23V across it (one-third of the battery voltage). Pin 7 is high impedance so current can flow from the battery to pin 7 and through D5, charging up the capacitor with a time constant of 3.3nF x 10kΩ = 33μs. When the capacitor charge reaches 2.47V, or around two-thirds of the battery voltage, the internal comparator connected to pin 6 ("threshold") is triggered.

This causes the internal flip-flop to change state, bringing output pin 3 high and pulling discharge pin 7 low. The 3.3nF capacitor then discharges due to current flow through the 10kΩ resistor between pin 6 and 7 and into the internal current sink at pin 7. Since the resistance and capacitance values are the same as during charging, the capacitor also discharges with a time constant of 33μs.

Once its charge reaches 1.23V (or whatever one-third of the supply voltage is at the time), the internal comparator flips the flip-flop again, output pin 3 goes low, pin 7 goes high-impedance and the cycle repeats.

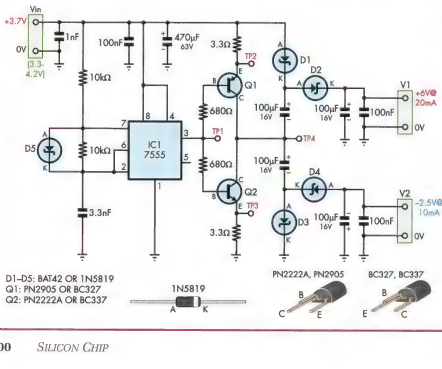
The resulting ~20kHz square wave from output pin 3 drives an inverting current buffer consisting of PNP transistor Q1 and NPN transistor Q2.

When the output is low, Q1's base-emitter junction is forward biased and its base current is limited to around 4.5mA by the 680Ω base series resistor. Current can then flow from the cell, through the 3.3Ω collector resistor and via Q1 to TP4.

When output pin 3 is high, Q1's base-emitter junction is not forward biased but Q2's is and again, its base current is limited to around 4.5mA by the second 680Ω series resistor. Q2 pulls TP4 down to 0V, via another 3.3Ω current-limiting/sense resistor. So the voltage at TP4 is an inverted version of IC1's output pin 3 voltage but Q1/Q2 can deliver a lot more current than IC1's output which is only rated for a few milliamps.

The waveform at TP4 drives two charge pumps, one of which forms a voltage doubler (based on schottky diodes D1 and D2) and one of which is a voltage inverter (schottky diodes D3 and D4). Both are based on charging and discharging 100μF electrolytic capacitors as the voltage at TP4 swings high and low.

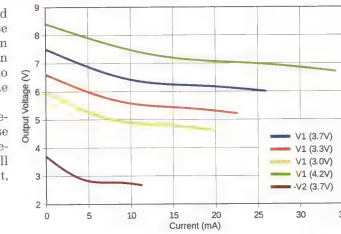
This results in around +7V at output V1 unloaded, with a nominally 3.7V Li-ion cell, and around -3V at V2 (unloaded). Even with a quite flat cell, at 3.3V and 25mA drawn from V1, the positive output is still around 5.2V; which is enough for a good low-dropout regulator to continue to provide a smooth 5V output. See the accompanying graph which shows the voltages at V1 and V2 based on the current and battery voltage.



Most op amps will work well with an unregulated negative rail but if you need to regulate it, you could use an LM385-1.2 (1.2V) or LM431 (2.5V) shunt regulator in combination with a limiting resistor, chosen based on the current draw of the op amp(s). The components to produce the negative output at V2 can be omitted if the negative rail is not required.

Note that more current can be delivered from this design by increasing the operating frequency, at the expense of increased quiescent current. For example, if you replace the 3.3nF capacitor with 470pF, the frequency will increase from 20kHz up to about 125kHz and as a result, the V1 and V2 voltage curves will be flatter.

Petre Petrov,
Sofia, Bulgaria. ($50)



PICAXE-based Dual Temperature Datalogger

This project was developed to assist with troubleshooting a faulty auto-defrost upright freezer. There was a need to observe instantaneous temperatures at a glance, know the minimum and maximum temperatures over a given period and also be able to log temperature at regular intervals over a day or more, for more detailed analysis.

It uses a PICAXE-20X2 which has additional input/output capability, higher speed (64MHz) and larger program capability, compared to the PICAXE20M2.

The circuit is very simple due to the use of relatively cheap I²C (two-wire serial bus) devices, including a Dallas DS3231 real-time clock (RTC), an Atmel AT24C32N 32kbit EEPROM (electrically erasable, programmable read-only memory) on the same module and a 20x4 I²C LCD module.

All these items are readily available from online retailers such as eBay for just a few dollars.

Two DS18B20 sensors are used. For example, they could be used to monitor fridge and freezer temperature, or they can both be placed in different locations in a freezer. The temperature in the vicinity of the defrost heating element and near the internal fan exhaust outlet can go as high as 50°C during a defrost cycle while the food temperature, hopefully, stays in the vicinity of -18°C. So monitoring both can be worthwhile.

The 20x4 I²C LCD screen was included to provide a "data at-a-glance" capability. The first line of the display shows the temperature reading from both sensors.

The second line shows the minimum temperatures recorded for both sensors. Likewise, the third line shows the maximum recorded temperatures and the fourth line shows the system time as hours, minutes and seconds.

The minimum and maximum readings are reset daily at 3am or by pushing switch S3. Although the DS18B20 sensors can range from -55 to +125°C, for software economy, the 20X2 program limits the range from -55 to +99.9°C.

The data logger functionality utilises the I²C AT24C32N EEPROM IC on the DS3231 RTC module for data storage. The logging interval is selected by first pushing button S6 to display the second screen of information on the LCD, then pushing button S4, which will then cycle through the various value options.

One logged event consumes eight bytes of data including the time, date and temperature value from both sensors.

For example, if the log interval is set to five minutes then the 32kbit (4KB) EEPROM provides about 42 hours of history. Once this is reached, the earliest data is written over and the program continues. It would be relatively easy to incorporate a larger I²C EEPROM like a 24LC512 to give more storage or alternatively, the logging interval could be extended to say 10 or 15 minutes with a proportional increase in stored history.

When button S2 is pressed, the entire contents of the EEPROM is dumped to the RS-232 port at 38,400 baud for capture on a laptop or PC using standard serial data capture software. During this process, the logged 12-bit temperature readings are converted to comma-separated readable ASCII characters by the 20X2 before being sent to the RS-232 port.

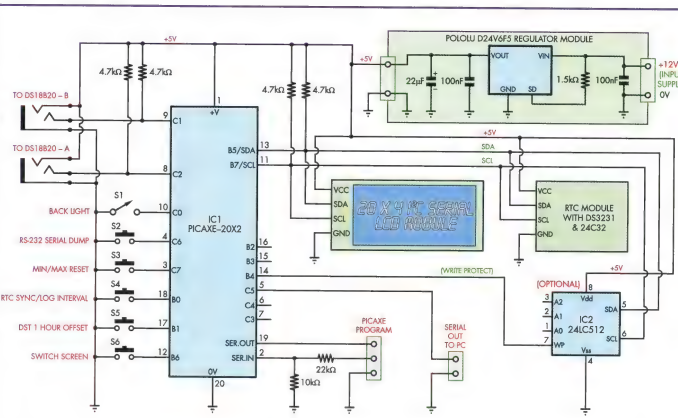
The resulting captured text file can then be imported into spreadsheet software and graphed easily for a more detailed view of what's been happening. From a graph, it's easy to determine the compressor run time, the defrost heater run time as well as temperature rise and fall times. See the accompanying graph for an example.

For my application, the DS18B20 sensors were mounted on the end of 3-strand rainbow ribbon cable fly leads. The ribbon cable is small and flat and sits snugly under the freezer door seal without compromising its integrity.

For flexibility, the other ends of the sensor cables are connected to the 20X2 via 3.5mm stereo plugs and sockets. You could use commercial available waterproof DS18B20 sensors with integral cables instead, if it suits your application.

Switch S1 turns the LCD backlight

continued next page



on and off while switch S5 adds or subtracts an hour from the system time, to compensate for daylight savings time (DST) starting or ending.

With the first screen display shown on the LCD (selected using S6), S4 allows for drift in the RTC to be easily corrected. To eliminate any ambiguity surrounding the RTC minutes value, pressing the switch causes the RTC seconds register to be set to "30". Note though that the time and date in the RTC need to be initially set using a PICAXE RTC setup program like that found in the PICAXE editor program.

Power for the circuit is provided by a 12V DC 1A plugpack feeding a Pololu D24V6F5 or 7805 5V DC regulator. A more elaborate battery backup system would be needed if continuous logging is required in the event of AC mains failure.

The circuit has proved very versatile since the original freezer fault that spawned the idea. The freezer was one of a pigeon pair and with the dual sensor, it was very easy to monitor and log both the freezer and adjoining fridge temperatures simultaneously.

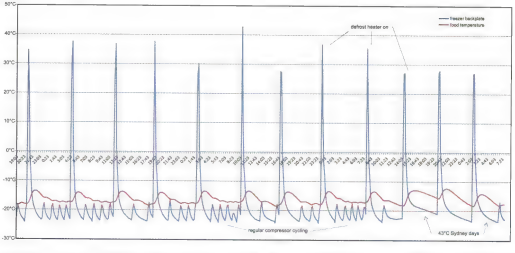
With everything operating normally, the logged data file can be saved for future reference if ever required. The accompanying chart shows the result of one logging session of around 3.5 days.

The unit has also been used to monitor the health of a domestic ducted air conditioner unit with one sensor monitoring and logging the supply air temperature and the other sensor monitoring the return air temperature.

The PICAXE-20X2 source code, named "20X2 dual temperature logger V11.bas" and available for download from the SILICON CHIP website, is extensive.

There is a lot of commentary in the program that helps explain the purpose of the various subroutines and how they interact to get the circuit working. The subroutines related to the I²C RTC and LCD may provide insights to readers pursuing their own projects involving these modules.

David Worboys,
Georges Hall, NSW. ($70)

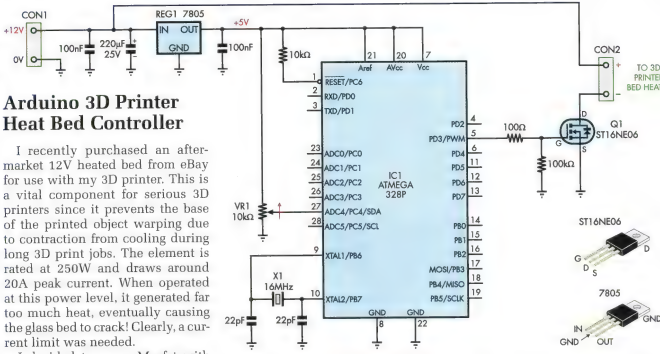


Arduino 3D Printer Heat Bed Controller

I recently purchased an aftermarket 12V heated bed from eBay for use with my 3D printer. This is a vital component for serious 3D printers since it prevents the base of the printed object warping due to contraction from cooling during long 3D print jobs. The element is rated at 250W and draws around 20A peak current. When operated at this power level, it generated far too much heat, eventually causing the glass bed to crack! Clearly, a current limit was needed.

I decided to use a Mosfet with PWM control to reduce the average power, and a pot to adjust it to the optimum heating level, depending on the ambient temperature and job. While there are plenty of analog PWM circuits around, I decided to use an Arduino.

The ATmega328P chip running the Arduino code controls the gate of Mosfet Q1 via its pin 5 PWM output. A 100Ω series resistor reduces ringing and overshoot while a 100kΩ resistor between the Mosfet gate and source ensures its stays off when the circuit is powered down. The Mosfet switches the negative side of the heater bed via terminal block CON2, with the other end going to the +12V rail from CON1.



CON1 also connects the incoming 12V power to a 5V regulator to power microcontroller IC1. It uses a 16MHz crystal and two 22pF load capacitors to time its internal clock. It measures the voltage at the wiper of potentiometer VR1 using its pin 27 analog input A4. This voltage increases as VR1 is rotated clockwise since it is connected across the 5V supply.

Note that dividing the analog pin voltage reading (of 0-1023) by six artificially limits the maximum PWM duty cycle to 66%, ie, 170 ÷ 256; the PWM duty cycle is an 8-bit value of 0-255. This prevents the heated bed from operating at more than 165W (2/3 of the rated 250W).

If this power cap was not desired, one could simply divide the result by four instead of six.

I loaded this software onto an ATmega328P chip that was purchased with the Arduino boot-loader preloaded. The process of programming the chip was done using another Arduino, ie, temporarily swapping the new chip into the Duemilanove board to program it using the Arduino IDE. I then soldered the chip and other components to a small PCB that I made using a CNC milling machine but it would be quite easy to build on breadboard or Veroboard using point-to-point wiring.

Pete Mundy,
Nelson, New Zealand. ($50)

The source code is as follows:

```
void setup() {                          // Setup code, run once at power-on
  pinMode(3, OUTPUT);
}

void loop() {                           // The following code repeats endlessly during operation
  int vr1Reading = analogRead(A4); // Read the value on analog pin 4 (vr1), result = 0-1023
  vr1Reading = vr1Reading / 6;          // Scale the value read down to range 0-170
  analogWrite(3, vr1Reading);           // Adjust duty-cycle of PWM driving signal for FET
}
```

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06/17

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NOTE: Not all PCBs are shown here due to space limits but the SILICON CHIP ONLINESHOP has boards going back to 2001 and beyond. For a complete list of available PCBs, back issues, etc, go to *siliconchip.com.au/shop* Prices are PCBs only, NOT COMPLETE KITS!

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ACTIVE DIFFERENTIAL PROBE BOARDS	SEP 2014	04107141/2	$10/SET
MINI-D AMPLIFIER	SEP 2014	01110141	$5.00
COURTESY LIGHT DELAY	OCT 2014	05109141	$7.50
DIRECT INJECTION (D-I) BOX	OCT 2014	23109141	$5.00
DIGITAL EFFECTS UNIT	OCT 2014	01110151	$15.00
DUAL PHANTOM POWER SUPPLY	NOV 2014	18112141	$10.00
REMOTE MAINS TIMER	NOV 2014	19112141	$10.00
REMOTE MAINS TIMER PANEL/LID (BLUE)	NOV 2014	19112142	$15.00
ONE-CHIP AMPLIFIER	NOV 2014	01109141	$5.00
TOR DONGLE	DEC 2014	04112141	$5.00
MULTISPARK CDI FOR PERFORMANCE VEHICLES	DEC 2014	05112141	$10.00
CURRAWONG STEREO VALVE AMPLIFIER MAIN BOARD	DEC 2014	01111141	$50.00
CURRAWONG REMOTE CONTROL BOARD	DEC 2014	01111144	$5.00
CURRAWONG FRONT & REAR PANELS	DEC 2014	01111142/3	$30/set

PRINTED CIRCUIT BOARD TO SUIT PROJECT:	PUBLISHED:	PCB CODE:	Price:
CURRAWONG CLEAR ACRYLIC COVER	JAN 2015	-	$25.00
ISOLATED HIGH VOLTAGE PROBE	JAN 2015	04108141	$10.00
SPARK ENERGY METER MAIN BOARD	FEB/MAR 2015	05101151	$10.00
SPARK ENERGY ZENER BOARD	FEB/MAR 2015	05101152	$10.00
SPARK ENERGY METER CALIBRATOR BOARD	FEB/MAR 2015	05101153	$5.00
APPLIANCE INSULATION TESTER	APR 2015	04103151	$10.00
APPLIANCE INSULATION TESTER FRONT PANEL	APR 2015	04103152	$10.00
LOW-FREQUENCY DISTORTION ANALYSER	APR 2015	04104151	$5.00
APPLIANCE EARTH LEAKAGE TESTER PCBs (2)	MAY 2015	04203151/2	$15.00
APPLIANCE EARTH LEAKAGE TESTER LID/PANEL	MAY 2015	04203153	$15.00
BALANCED INPUT ATTENUATOR MAIN PCB	MAY 2015	04105151	$15.00
BALANCED INPUT ATTENUATOR FRONT & REAR PANELS	MAY 2015	04105152/3	$20.00
4-OUTPUT UNIVERSAL ADJUSTABLE REGULATOR	MAY 2015	18105151	$5.00
SIGNAL INJECTOR & TRACER	JUNE 2015	04106151	$7.50
PASSIVE RF PROBE	JUNE 2015	04106152	$2.50
SIGNAL INJECTOR & TRACER SHIELD	JUNE 2015	04106153	$5.00
BAD VIBES INFRASOUND SNOOPER	JUNE 2015	04104151	$5.00
CHAMPION + PRE-CHAMPION	JUNE 2015	01109112/2	$7.50
DRIVEWAY MONITOR TRANSMITTER PCB	JULY 2015	15105151	$10.00
DRIVEWAY MONITOR RECEIVER PCB	JULY 2015	15105152	$5.00
MINI USB SWITCHMODE REGULATOR	JULY 2015	18107151	$2.50
VOLTAGE/RESISTANCE/CURRENT REFERENCE	AUG 2015	04108151	$2.50
LED PARTY STROBE MK2	AUG 2015	16101141	$7.50
ULTRA-LD MK4 200W AMPLIFIER MODULE	SEP 2015	01107151	$15.00
3-CHANNEL REMOTE CONTROL RECEIVER	SEP 2015	15108151	$15.00
MINI USB SWITCHMODE REGULATOR MK2	SEP 2015	18107152	$2.50
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	OCT 2015	01205141	$20.00
ULTRA LD AMPLIFIER POWER SUPPLY	OCT 2015	01109111	$15.00
ARDUINO USB ELECTROCARDIOGRAPH	OCT 2015	07108151	$7.50
FINGERPRINT SCANNER – SET OF TWO PCBS	NOV 2015	03109151/2	$15.00
LOUDSPEAKER PROTECTOR	NOV 2015	01110151	$10.00
LED CLOCK	DEC 2015	19110151	$15.00
SPEECH TIMER	DEC 2015	19111151	$15.00
TURNTABLE STROBE	DEC 2015	04101161	$5.00
CALIBRATED TURNTABLE STROBOSCOPE ETCHED DISC	DEC 2015	04101162	$10.00
VALVE STEREO PREAMPLIFIER – PCB	JAN 2016	01101161	$15.00
VALVE STEREO PREAMPLIFIER – CASE PARTS	JAN 2016	01101162	$20.00
QUICKBRAKE BRAKE LIGHT SPEEDUP	JAN 2016	05102161	$15.00
SOLAR MPPT CHARGER & LIGHTING CONTROLLER	FEB/MAR 2016	16101161	$15.00
MICROMITE LCD BACKPACK, 2.4-INCH VERSION	FEB/MAR 2016	07102121	$7.50
MICROMITE LCD BACKPACK, 2.8-INCH VERSION	FEB/MAR 2016	07102122	$7.50
BATTERY CELL BALANCER	MAR 2016	11111151	$6.00
DELTA THROTTLE TIMER	MAR 2016	05102161	$15.00
MICROWAVE LEAKAGE DETECTOR	APR 2016	04103161	$5.00
FRIDGE/FREEZER ALARM	APR 2016	03104161	$5.00
ARDUINO MULTIFUNCTION MEASUREMENT	APR 2016	04116011/2	$20.00
PRECISION 50/60HZ TURNTABLE DRIVER	MAY 2016	04104161	$15.00
RASPBERRY PI TEMP SENSOR EXPANSION	MAY 2016	24104161	$5.00
100DB STEREO AUDIO LEVEL/VU METER	JUN 2016	01104161	$15.00
HOTEL SAFE ALARM	JUN 2016	03106161	$5.00
UNIVERSAL TEMPERATURE ALARM	JULY 2016	03105161	$5.00
BROWNOUT PROTECTOR MK2	JULY 2016	10107161	$10.00
8-DIGIT FREQUENCY METER	AUG 2016	04105161	$10.00
APPLIANCE ENERGY METER	AUG 2016	04116081	$15.00
MICROMITE PLUS EXPLORER 64	AUG 2016	07108161	$5.00
CYCLIC PUMP/MAINS TIMER	SEPT 2016	10108161/2	$10.00/pair
MICROMITE PLUS EXPLORE 100 (4 layer)	SEPT 2016	07109161	$20.00
AUTOMOTIVE FAULT DETECTOR	SEPT 2016	05109161	$10.00
MOSQUITO LURE	OCT 2016	25110161	$5.00
MICROPOWER LED FLASHER	OCT 2016	16109161	$5.00
MINI MICROPOWER LED FLASHER	OCT 2016	16109162	$2.50
50A BATTERY CHARGER CONTROLLER	NOV 2016	11111161	$10.00
PASSIVE LINE-TO PHONO INPUT CONVERTER	NOV 2016	01111161	$5.00
MICROMITE PLUS LCD BACKPACK	NOV 2016	07110161	$7.50
AUTOMOTIVE SENSOR MODIFIER	DEC 2016	05111161	$10.00
TOUCHSCREEN VOLTAGE/CURRENT REFERENCE	DEC 2016	04110161	$12.50
SD200 AMPLIFIER MODULE	JAN 2017	01108161	$10.00
60V 40A DC MOTOR SPEED CON. CONTROL BOARD	JAN 2017	11112161	$10.00
60V 40A DC MOTOR SPEED CON. MOSFET BOARD	JAN 2017	11112162	$12.50
GPS SYNCHRONISED ANALOG CLOCK	FEB 2017	04202171	$10.00
ULTRA LOW VOLTAGE LED FLASHER	FEB 2017	16110161	$2.50
POOL LAP COUNTER	MAR 2017	19102171	$15.00
STATIONMASTER TRAIN CONTROLLER	APR 2017	09103171/2	$10.00/set
EFUSE	APR 2017	04102171	$7.50
SPRING REVERB	APR 2017	01104171	$12.50
6GHZ+ 1000:1 PRESCALER	MAY 2017	04112162	$7.50
MICRO8RIDGE	MAY 2017	24104171	$2.50
MICROMITE LCD BACKPACK V2	MAY 2017	07104171	$7.50

NEW THIS MONTH

10-OCTAVE STEREO GRAPHIC EQUALISER PCB	JUN 2017	01105171	$12.50
10-OCTAVE STEREO GRAPHIC EQUALISER FRONT PANEL	JUN 2017	01105172	$15.00
10-OCTAVE STEREO GRAPHIC EQUALISER CASE PIECES	JUN 2017		$15.00

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ASK SILICON CHIP

Got a technical problem? Can't understand a piece of jargon or some technical principle? Drop us a line and we'll answer your question. Send your email to silicon@siliconchip.com.au

Li'l Pulser Mk2 reverse speed control problem

I have built two Li'l Pulser Mk2 controllers (January 2014) and so far they both appear to work perfectly on the bench. But when I connect them up to some tracks with an engine, in both cases, putting them into reverse with the speed control fully anti-clockwise results in the voltage across the rails dropping to zero.

I have used the Altronics S4190D DPDT relay on both units. At full speed, there is a difference of nearly 1V between forward and reverse. Is this normal? (R. H., Campbelltown, NSW)

● With the speed control fully anti-clockwise, there should be the minimum track voltage across the rails, as set by VR2 (Min Set). That would be the case regardless of whether the setting is for forward or reverse.

So maybe there is a problem with the relay contacts where power is not being switched properly. It does seem strange that you have the same problem with two Li'l Pulsers.

There really shouldn't be any difference in output voltage (except for polarity) in forward or reverse as the relay only swaps the voltage over. There must be some interconnection happening when reverse is connected to change the speed control. Check that there isn't a short-circuit or incorrect wiring if you made the changes shown in January 2014. There could be an interconnection at S3, the Q or $\overline{Q}$ outputs of IC4a or Q3.

You could isolate the fault by manually shorting Q3's collector to its emitter to select reverse and check if the output voltages change in reverse. That may isolate the problem either to the relay contacts, if the problem is still present, or to the relay coil switching via Q3 and IC4a if it then works normally.

White noise source desired

Has SILICON CHIP ever published a circuit for a good quality white noise generator? I tried a circuit I found on the internet but it was pretty useless. That might be a useful project if it hasn't been published already. (B. P., Dundathu, Qld)

● We published a Pink Noise Source for Tinnitus Sufferers in September 2001. This had a switch to give either pink or white noise.

You can see a free 2-page preview of this article at www.siliconchip.com.au/Issue/2001/September/Personal+Noise+Source+For+Tinnitus+Sufferers

Questions about building a TENS unit

In August 1997, you published a project entitled "Transcutaneous Electrical Neural Stimulation". I am considering building this device. Can you tell me if the kit is still available? Since the project was released as a kit, have you received any feedback regarding the effectiveness of the device? And has SILICON CHIP any reasons to now doubt the effectiveness or safety of the device?

Do you know if now, with the advance of electronics, it would be cheaper to buy a manufactured device that may work more effectively? (R. Z., Craigburn Farm, SA)

● The August 1997 TENS unit kit and PCB are unavailable. The latest TENS unit we published was in January 2006, see: www.siliconchip.com.au/Issue/2006/January/Pocket+TENS+Unit+For+Pain+Relief (errata in the July 2016 issue: www.siliconchip.com.au/Articles/Errata/2587/7966).

This TENS unit can be highly effective and is safe. You can purchase the printed circuit board (PCB) and front panel artwork from our website, see: www.siliconchip.com.au/Shop/?article=2532

Other parts are commonly available from Jaycar or Altronics. The IR2155 can be replaced with the IR2153 which is available from www.futurlec.com/Others/IR2153pr.shtml The trimpots can be obtained from element14 (listed by their old name, Farnell, in the parts list).

GPS Analog Clock Driver problem

I have recently bought GPS Synchronised Clock boards from SILICON CHIP and have put together one of the boards, for a stepping movement. My problem is that I can not get it to work reliably. When observing the PIC output to the pins of CON1, the positive pulse is 1.5V DC but the negative pulse is less than 1V DC (~0.8V).

It would appear that the PIC16F88 or the PIC16LF88 (I have both) will not pull the output to ground. The clock mechanism works OK by alternating a 1.5V battery as suggested in the 2017 February article. Do you have any ideas? The clock mechanism is

Magnavox loudspeaker details wanted

I'd like to find out if anyone has information about the Australian Magnavox loudspeaker production at their factory at Mascot.

All I know is that in the 1960s, *Electronics Australia* published details of an 8-30 bookshelf system and they made very reasonably-priced loudspeakers with woofers up to 15 inches. I would be grateful for any details of their production and what happened to the company. If any readers have information, please send the details to lgeorge3@bigpond.com (L. G., Cowes, Vic)

● The original article was published in *Electronics Australia, January 1971* and a later article was published in *Electronics Today, August 1971*. We would be interested to hear if any reader knows about Magnavox's history in Australia too.

Soft Starter for power tools failed driving water pump

I recently finished building the Jaycar Soft Starter for Power Tools kit, KC5511, based on the SILICON CHIP article in the July 2012 issue. The unit worked OK for a couple of days but now seems to have failed. Opening up the box reveals that the NTC thermistors have fallen apart.

I have two 150W solar panels feeding into an MPPT Solar Charge Controller and then into a 150Ah AGM Deep Cycle Battery which powers a 2000W inverter.

The Soft Starter is used so that we can run a 1400W water pump off the inverter, supplying water to our house. The inverter won't start the pump without the Soft Starter. The water pump runs for one to two minutes on average 18 times a day in daylight hours.

After the first couple of days of normal operation, it failed after a couple of starts on an overcast day. Can you suggest what might have gone wrong? (Robert, via email)

● It's likely that this problem occurred because a water pump will draw a higher current for longer than the power tools the Soft Starter was designed to handle, so risks overheating and damaging the thermistors.

Basically, the thermistors are OK if the load's current draw drops to a normal level after a fraction of a second but the pump could effectively act like a short circuit for several seconds as it's starting under load and so the thermistor dissipation will be a lot higher.

We can offer two possible solutions. The first is to replace the two SL32 10015 NTC thermistors with two MS35 10018 NTC thermistors. These are somewhat larger so it may be tricky fitting them into the existing case/PCB.

However, they have a much higher instantaneous power rating and the same resistance, so the resulting unit should be more robust. They are also more expensive, at around $10 each.

The other option is to replace the two 10Ω 15A series NTC thermistors with four 5Ω 20-25A series NTC thermistors.

These will have roughly the same effectiveness at providing a soft start facility due to having the same 20Ω series resistance but will handle a high inrush current for longer without risking damage.

We suggest using four SL32 5R020 in place of the two SL32 10015. They're basically the same size so fitting them in the box would be tricky.

Possibly a larger box would be required or mount two of them under the board with the leads carefully insulated with heatshrink tubing to ensure safety. The cost is lower than the other solution as they are about $2.50 each.

As well as having higher inrush/current ratings, with four in series, the voltage across each would be half as much as with two, providing an improvement in robustness of roughly 2.5 times. Hopefully that would be enough for your application.

from Jaycar, Cat No XC-0100. (M. M., Baldivis, WA)

● The firmware for the GPS Clock was recently updated (on the 21st March) which fixes a problem with RA1 (pin 18) not toggling properly on the stepping version of the clock. Depending on when you programmed the chip, you might not have gotten this update; the firmware's version number can be checked when loading the setup menu in a terminal emulator (we were subsequently informed that the new version of the software fixed this problem).

Micromite Plus Explore 64 with a touchscreen

Do you have any information or a PCB design to connect an LCD touch screen to a Micromite Explore 64? (C. B., Manypeaks, WA)

● It should be possible to figure out how to hook up an LCD Touchscreen to the Explore 64 using the information on pages 72 and 73 of the August 2016 issue and the Micromite Plus LCD BackPack circuit diagram on page 68 of the November 2016 issue, plus the instructions on pages 72 and 73 of that same issue.

The critical point to understand here is that the Micromite Plus LCD BackPack is essentially the Explore 64 in a different form factor with a serial LCD Touchscreen connected.

Assuming you are using a serial touchscreen, you just need to connect it to the same pins as used in the Plus LCD BackPack (via CON3) and then issue the commands given in that article, possibly changing the controller model number if your LCD uses a different controller.

If you are using a parallel touchscreen it's a bit more complex and we suggest you read the Explore 100 articles (September & October 2016) and then figure out which pins numbers to change for the 64 pin micro compared to the 100 pin micro. In that case, it would also be a good idea to read the Micromite Plus PDF manual.

Where to find 30V centre-tapped plugpack

Where can I obtain the 30V centre-tapped plugpack for the 4-Output Universal Voltage Regulator (May 2015)? I have Googled high and low without success! Can you point me in the right direction without going via China? (B. T., Rosebud, Vic)

● We didn't specify a 30V centre-tapped plugpack in that article. Table 1 on page 80 makes reference to a 30VAC centre-tapped transformer and various plugpacks ranging from 9VAC up to 17VAC.

Normally, you would use a 15VAC or 17VAC plugpack in voltage doubling mode (ie, one end connected to the centre tap position) in order to get 15V outputs or similar from a plugpack (see Fig.3 on page 83, May 2015).

We have seen centre-tapped plugpacks before but they're rare and the highest output voltage we have seen was 18VAC centre-tapped (ie, 9-0-9V).

Temperature control for noisy UPS fans

I have a big 3000VA UPS. When I turn it on, the two 12V square computer fans spin at full speed and are quite noisy and the fans run for an hour, even though the big transformer and the two heatsinks are cold.

I don't understand why they didn't simply design the UPS to spin the fans up when the temperature was above

Building model railway controllers for larger scale locomotives

I read with much interest your recent article in the March 2017 issue of SILICON CHIP on the Stationmaster PWM model railway track controller. It compares favourably with the Railpower IV PWM controller published in the September 2008 issue.

I purchased and built a kit for that project which works admirably. However, the controller I most favour was published in *Electronics Australia* magazine, May 1974 and was called the "Inertia Train Control", of which I have built several over the years.

All these controllers work extremely well with the more popular N & HO scale model trains, for which they were designed. The larger scales (S, O & G) require something a bit more robust, as some of the larger locos may draw in excess of 5A.

As well as realistic operation which these controllers provide, in today's modelling world sound is also becoming more and more utilised to create a sense of realism. Most of the sound cards available do not like PWM control. It tends to damage them to some extent (I know from experience; very expensive).

I have built many different controllers over the years but the controller I have had most success with is the ITC controller from 1974.

I now model in G scale and find this controller hard to beat. The components have been upgraded to handle the extra power and voltage (24V) and I've substituted a 5A circuit breaker in place of the light bulb.

The "kick" circuit has been eliminated as it is unnecessary and the adjustments for braking and inertia have been mounted externally. Voltand ammeters have been added to the output circuit prior to the reversing switch. (I have heard of a similar circuit being adapted to ride-on 7.1/4" gauge locos running on battery power).

The only problem I have found is that the throttle potentiometer becomes very hot during operation. I have used large wire-wound ceramic pots previously with no apparent problem, but they seem to be no longer readily available.

There are controllers available commercially for the larger scales, but I have found the cost to be prohibitive. Can you please provide a solution to the overheating of the throttle control? Could this controller be re-visited in a future article? (T. H., Maryborough, Qld)

● This very old circuit is a bit of a joke since it is only a Darlington follower. The throttle pot is overheating because of the higher current demand from the Darlington and it clearly needs a higher beta transistor in place of TR1. We suggest using a BD681 Darlington.

The idea of applying full voltage using relay, C3, D4 etc is extremely crude and best omitted, as you have found.

It should be possible to use PC sound cards in conjunction with the PWM track voltages from modern train controller although it would be necessary to filter the signal so that a smoothed average voltage was applied to the sound card input.

a particular level or even better, turn them on above a particular threshold (say 50°C) and then speed up the fans if the temperature increased further. Can you suggest how I can overcome this problem? (S. W., Murwillumbah, NSW)

● You could place a resistor in series with the supply connecting to both fans (try 33Ω 5W) to slow the fans. Then use a 50°C normally open thermostat (Jaycar ST3831) mounted on the UPS heatsink, with its contacts wired across the resistor so they short out the resistor when the heatsink temperature rises above 50°C.

Converting monophonic recordings to stereo

I was fascinated by some websites that I recently looked at, concerning the conversion of monophonic recordings to true stereo, using "spectral analysis". This seems like magic to me, since I hark back to the era of reel to reel tape recorders and vinyl records.

Apparently, it can sometimes take months to process one recording but that may change if recent university CPU research (web search: "kilocore") is commercialised, to produce PCs running 100 times faster than today's.

Is this the sort of technology that SILICON CHIP magazine might be able to simplify for people like me in a feature article? (P. W., Meadowie, NSW)

● There is no directional information contained in any monophonic recording. There are two ways in which a stereo signal could be created (or simulated) from a mono recording.

The first is to give some sort of spread using a comb filter (digital or otherwise) to give a simulated stereo signal. You can see a practical version using the comb-filter technique and a bucket brigade device in our June 1996 issue (A High-Performance Stereo Simulator, by John Clarke).

On the other hand, with a huge amount of signal processing, it might be possible to take the sounds of solo instruments in a mono recording and switch them into one channel or another, in a kind of multiplexing system. However, the processing required to do this with a monophonic recording of massed instruments would make it infeasible.

Building Loudspeaker Protector without SMDs

I would like to build the Universal Speaker Protector, described in the November 2015 issue, but with through-hole components. I am laying out a new PCB to achieve this. I have searched for replacement components and would like to ask if these are OK:

- for BDP953 substitute MJE182G
- BAW99 – what is the correct substitute?
- BAW56 – what is the correct substitute?
- for BC846, substitute BC546
- for BC856, substitute BC556

Others components like resistors, capacitors and the LM339 have direct through-hole equivalents. What do you think? (Robert, Hungary)

● Your suggested substitutions seem fine. BC846/BC546 and BC856/BC556 are identical except for the packaging.

For BAV99, you can use two series-connected 1N4148 diodes. For

Stationmaster clarifications and solar suggestion

Thank you for publishing my Stationmaster project in your March 2017 issue.

Please note that I tested several locomotives with small motors with the prototype, including a Portescap drive as well as a variety of others like Spuds and Lima and all performed well, although a combination of flywheels and inertia settings for normal locos made you wait around for a while before there is "movement at the station".

Regarding the question "Is Stationmaster safe for locomotive motors?" on page 90 of the April issue (Ask SILICON CHIP section), H. M. had the experience of a model locomotive motor fail when using an older PWM controller design.

Possibly this was due to a high voltage 50Hz or 100Hz ripple superimposed on the PWM output of that controller.

The likelihood of that occurring depends on the power supply that's driving the PWM controller. These days, regulated switchmode supplies are pretty common and cheap and have little 50/100Hz ripple, so constructors can use a regulated DC supply to be on the safe side.

I note that you changed the specification of the 2.2µF capacitors; I used tantalum (polarised) capacitors in my prototype but you have specified ceramics and removed the polarity markings from the PCB.

If constructors did want to use tantalums instead, the positive leads would need to be on the side towards the two adjacent 100nF capacitors in each case.

Note also that I used a 100nF SMD capacitor in my prototype, rather than the 1µF specified, although I suspect it won't make much difference either way.

Regarding running a battery charger off a grid-tied solar system in the event of a blackout, if I was so driven, I would wire in a mains-sustained contactor in the solar DC supply line such that it handed over DC to a UPS with sufficient capacity in the event of a grid failure.

I would also wire a mains sustained contactor on the house incoming line to isolate the mains supply side while the grid was down.

A cross-feeding sensing method could be created for islanding which re-connected the grid when the solar output was unable to sustain the demand within a single phase system because a three phase system supply would make the whole thing very complicated and expensive.

The solar inverter could not do anything until the incoming power was re-applied and solar DC re-presented to the inverter by the changeover DC contactor. A UPS with the correct DC input level would have to be sourced to accommodate the unique solar voltage output on the roof. (Bob Sherwood, Perth, WA)

- A UPS can only supply power until its battery is discharged to the cut-off point. It would not be able to take advantage of the power from the solar panels during a blackout, to keep its battery charged, because the battery in most uninterruptible power supplies is 12 or 24V not the 350V+ from a rooftop solar panel array.

BAW56, use two 1N4148 diodes with the anodes joined together.

Web Server In A Box downloads

I have a Web Server In A Box kit (WIB), based on the design from November-December 2009. I purchased this kit not long after it was released but have not found time to assembling it yet and was now thinking of doing so.

The project requires a file, "ewswebsite.zip", which I can't seem to find on your website (or anywhere else for that matter). Is it still available? The main question though is whether the WIB still work with current browsers. I've just read though a whole pile of old postings on a couple of blog sites and noted various problems people were having. (B. P., Toowoomba, Qld)

- The WIB downloads, including website files, are available from www.siliconchip.com.au/Shop/6/1083

We don't know of any reason why it wouldn't work with modern browsers. After all, they still use HTTP (which it supports) and the content of the HTML files is up to you.

Heat Controller wanted

I wish to obtain a kit suitable to use as a temperature control for a single bar heater rated at 10A, 240VAC. Please advise. (C. B., Strathalbyn, SA)

- A heater controller was published in the July 1998 issue of SILICON CHIP. A back issue can be purchased from: www.siliconchip.com.au/Shop/Back+Issues+%28Printed%29/Silicon+Chip+Back+Issue+-+July+1998

No kit is available, however we can supply the PCB. See: www.siliconchip.com.au/Shop/?article=4687 The other parts you need to build it are available from Jaycar or Altronics.

Programming the Nixie Clock with the Cheap PIC32 Programmer

I have been trying to update the firmware in the Nixie Clock Mk2 (February-March 2015) with the file 1910215G.hex downloaded from your website using the Cheap PIC32 Programmer described in the November 2015 edition of you magazine.

Programming appears to be successful however the clock will not boot up with the new micro. I have tried two different micros programmed several times each. Is there an issue with the HEX file or am I missing something? (P. B., Balhannah, SA)

- We have verified that the rev G HEX file on the website is identical to the file we use to program PICs which are supplied with the kits. So it seems either there's a problem with the Cheap PIC32 Programmer which is not programming the chip correctly, or you have some other problem with your Nixie Clock.

Ensure that the supercap is discharged before reinserting the PIC so that you aren't connecting the chip to live power pins and make sure that all the pins are going into the socket correctly.

It's tricky to insert the chip into the socket after clock assembly is

complete, although we have done it successfully on several occasions. Alternatively, use the in-circuit programming header so you don't have to remove the chip.

Modifying 2008 LED Strobe for higher power

I built the LED Strobe described in the August 2008 issue of SILICON CHIP, using a K2510 kit from Altronics.

The unit functions but I find it difficult to use unless the ambient lighting can be significantly lowered, which is not always practical. Would it be possible to utilise a different and more powerful LED and what would be involved in doing such a modification? (B. D., Hope Valley, SA)

● For a higher current LED, you could replace the BC337 transistor (Q1) with a logic-level Mosfet so that more current can be delivered to a LED.

The gate of the Mosfet would connect to where the transistor base would connect, source to the emitter connection and the drain to the collector position for the transistor.

The value and power rating of the series resistor for the LED (originally 39Ω 5W) will need to change. For a 3W LED, the LED would typically have 3V across it and so the current for the LED needs to be 1A (3W ÷ 3V) or less. For the 12V supply, the series current limiting resistor value is calculated as (12V - 3V) ÷ 1A, ie, 11Ω. The next available value is 12Ω.

The power rating will need to be higher, ie, at least (12V – 3V) × 1A = 10W. Four 12Ω 5W resistors could be used, in a series/parallel arrangement.

If you use a LED module that has its own current limiting (ie, is designed to run directly from a 12V supply) then a series resistor is not needed.

Note that the DC socket, CON3, 3.5mm socket CON3, diode D1 and switch S5 are not rated for the continuous current for a 3W or higher-rated LED and so separate suitably rated wiring will be needed.

In addition, the drain and source of the Mosfet will need to be connected with suitable wiring, with the source directly to the 0V supply connection. A suitable Mosfet is the CSD18534KCS logic-level Mosfet which is available from:

www.siliconchip.com.au/Shop/7/4177

The Mosfet may need heatsinking if the current causes the device to run hot.

Boat voltage monitor required

I hope SILICON CHIP or a reader can help with some advice to solve the following problem. The marina at our club has shore power bollards for supply of 230VAC to our boats. The problem occurs when, for whatever reason, the circuit breaker trips to my bollard and it goes off.

There is no visual indication on any bollard to indicate this, so the owner does not find out until he goes on-board in perhaps a week or so.

As there is now no battery charging and the fridge/freezer is full of food and switched on, it is only a matter of time before the house batteries go flat and then on to battery heaven. This is followed shortly after by a huge pong from the boat as $200 plus of food goes down the gurgler; not to mention $1500 for new batteries!

Another potential major issue is the now non-operation of all the bilge pumps to pump out rain and seawater that inevitably seeps in through rudder and shaft glands etc.

In a worst-case scenario where you may be away for a month or more, it may not become immediately apparent to other club members that your Plimsoll line has disappeared below water and your pride and joy is looking more like a submarine.

So has SILICON CHIP ever produced a project that detects the loss of a normally permanent voltage and then calls a mobile phone (mine) to advise via a message/tone that my shore power is now off and I can then call for assistance if I can't make it there myself?

As this type of scenario would apply in many other similar situations, where it may be damaging, dangerous or expensive to lose power, this may be a worthwhile project to consider.

A less complicated indication could be a bright flashing strobe light on the top of the radar tower, triggered when shore power is lost, but it would need to switch off automatically, when the shore power is switched back on. At least this would attract attention quickly.

Is there a past SILICON CHIP project that would do this? My 2010 SILICON CHIP Ultrasonic Anti-Fouling kit has been working a treat but it won't fix this problem. I look forward to your help. (R. L., Yarra Glen, Vic)

● That's a nasty problem to have and we would really want to know what was tripping the circuit breaker.

Since it is intermittent, we wonder if it is related to the battery charger (is it a switchmode type?) and the bilge pumps?

Have you tried operating the bilge pumps (with water present in the bilge) to see if they cause the tripping? Then it would be a case of checking the battery charger to see if it is the problem.

It is possible that EMI suppression capacitors in the input network to the battery charger are triggering the shore power circuit breaker when the bilge pumps kick in.

Anyway, it just so happens that we have published the ideal project to monitor your boats' functions with this Arduino-based GSM remote monitoring station. It will phone you when a problem arises.

See www.siliconchip.com.au/Issue/2014/March/Arduino

However, all GSM networks are due to cease operation soon and 3G/4G networks are replacing them. So we are looking at updating the project to use the 3G network.

Connecting USB Data Logger to a modern PC

I have just finished assembling a USB Data Logger kit (December 2010). Unfortunately, there is some unknown issue connecting the data logger to a PC host, I get the message "USB device not recognised. The last USB device connected to this computer malfunctioned and Windows does not recognise it". Then it disconnects.

The power LED on the datalogger flashes several times (5-20x) at about 1Hz when plugged in or after pressing S2 running on battery power.

It does not make a difference whether the SD card is inserted or

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not, or whether I press S2 quickly or keep it pressed for about two seconds or longer. I am using two 1.2V 900mAh NiMH cells, the total voltage across them is 2.7V. The voltage between GND and V3.3_out on COM3 is 3.3V.

I think I did a decent job assembling the unit and can not see any faults. I use the USB ports on my host PC frequently for other devices without any difficulties. Do you have an idea what the problem might be? (O. G., via email)

● When that project was designed, the latest version of Windows was Windows 7. So that is the version which was used to test the software for that project.

Windows 8 and Windows 10 by default will not install an unsigned driver. It's necessary to disable this checking, at least temporarily, before it's possible to install the driver for the USB Data Logger. Some information on how to do this is available at the following link: www.howtogeek.com/167723/how-to-disable-driver-signature-verification-on-64-bit-windows-8.1-so-that-you-can-install-unsigned-drivers/

(We received the following response to our solution: "This worked, disabling the driver signature. I can now connect to the unit and everything looks OK.") SC

Next Month in Silicon Chip

Using a DDS Module for AM Radio IF Alignment

In this article, we present updated software and slight tweaks to the hardware of the Micromite BackPack Touchsreen DDS Signal Generator described in the April issue. These changes make it a cinch to align the IF stage of a transistor or valve-based superheretodyne AM radio.

Rohde & Schwarz RTB2004 DSO Review

We take a look at this latest offering from R&S which combines a 10-bit ADC and 10.1-inch capacitive touchscreen along with either two or four channels in a compact bench-top unit.

New Developments in LED Lighting

We take a look how LEDs are now rapidly supplanting all other forms of domestic lighting whether it is incandescent, fluorescent (strip lighting and CFL) or 230VAC and 12V halogen. But LEDs are often not dimmable or cannot be dimmed with conventional dimmers. We tell you what you need to know.

Emergency Brake Warning for your Car

Brake lights are important in warning people behind you when you're stopping but the problem is that they light up whether you're barely pressing the pedal or are pressing as hard as you can. This project will add a feature of many premium vehicles to just about any car: rapid flashing of the hazard lights under heavy braking, to warn any tailgater that you will soon be stationary!

Note: these features are prepared or are in preparation for publication and barring unforeseen circumstances, will be in the next issue.

The July 2017 issue is due on sale in newsagents by Thursday June 29th. Expect postal delivery of subscription copies in Australia between June 29th and July 14th.

Notes & Errata

Micromite LCD BackPack V2, May 2017: in the parts list on page 89 it lists 4 M3 x 12mm pan-head machine screws. They should instead be M3 x 6mm (M3 x 8mm may also work). Also omitted from the parts list is the jumper shunt and 2-pin male header needed for JP1, and in Fig.1 JP1 is mistakenly labelled as LK1; the PCB overlay is correct. The kit we supply comes with the correct parts.

ATmega-based Metal Detector with stepped frequency indication, Circuit Notebook, March 2017: the circuit diagram published is missing two 10kΩ resistors, one of which is connected between the anode of D1 and pin 27 of IC1 and the other goes between pin 27 and ground. This allows IC1 to monitor the battery voltage and display it on the LCD.

Advertising Index

Altronics	INSERT
Dave Thompson	111
Digi-Key Electronics	3
ECADtools	92
Emona Instruments	IBC
H K Wentworth/Electrolube	8
Hare & Forbes	OBC
High Profile Communications	111
Icom	9
Jaycar	IFC,53-60
Keith Rippon Kit Assembly	111
LD Electronics	111
LEDsales	111
Master Instruments	111
MathWorks	93
Microchip Technology	17
Mouser Electronics	7
Oatley Electronics	11
Ocean Controls	43
Pakronics	5
PCB Cart	77
QualiEco Circuits Pty Ltd	51
Rockby Electronics	27
Sesame Electronics	111
SC Online Shop	99,104-105
SC Radio & Hobbies DVD	45,71
Silicon Chip Binders	80
Silicon Chip Subscriptions	85
Silicon Chip Wallchart	76
Silvertone Electronics	8
Tronixlabs	6,111
Vintage Radio Repairs	111

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